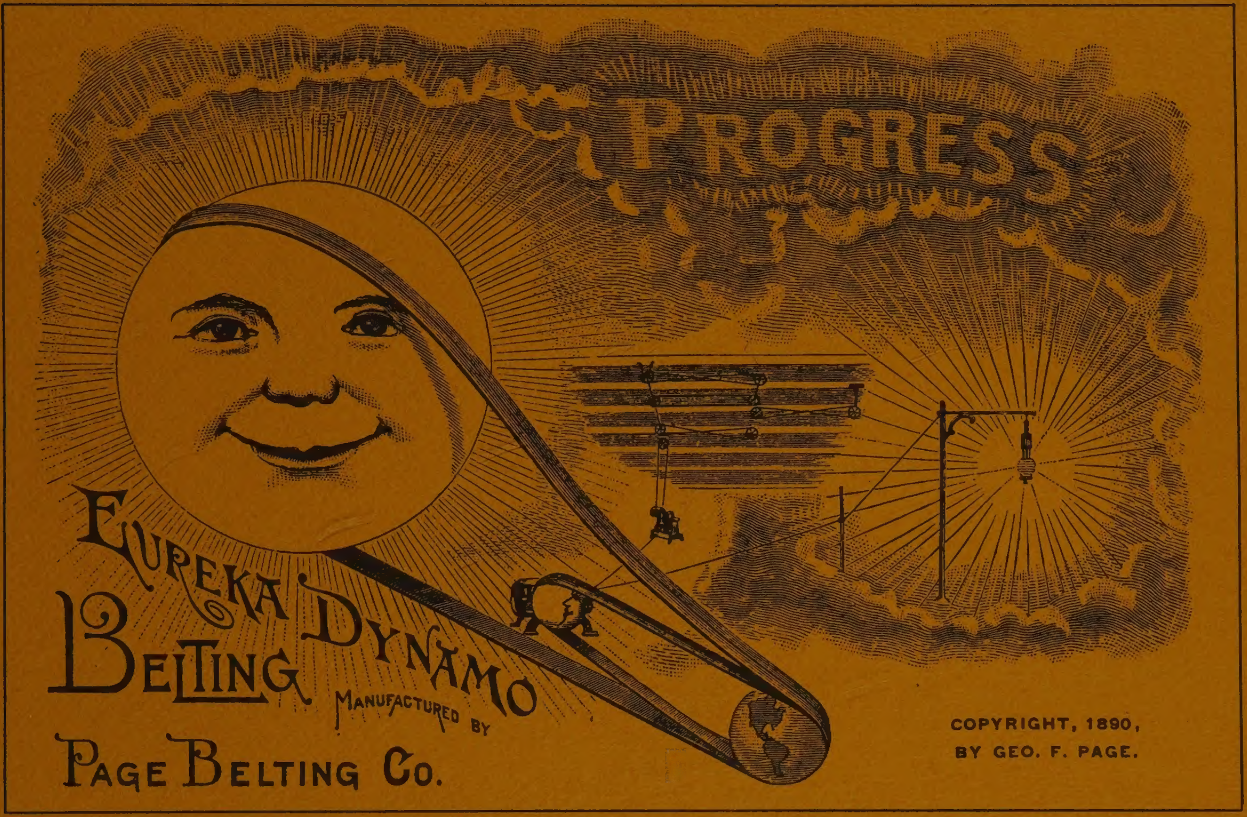
IA THE JOURNAL OF THE SOCIETY FOR INDUSTRIAL ARCHEOLOGY



Volume 19, Number 1 1993

IA publishes original articles about surviving industrial sites, structures, and equipment that combine the insights of field work and historical research. It is also concerned with conservation, adaptive re-use, museology, instructional techniques, and methodology—especially with the relationship between industrialization and parallel historical themes. In all cases the ultimate aim of the journal is to promote understanding of the industrial age by focusing on physical remains, whether they be aboveground or below.

The aims of the journal are those of the Society for Industrial Archeology, and the particular objective of the journal is to advance industrial archeology as a discipline. As any field matures, it shifts from an emphasis on pure description to a greater concern with explanation. Thus, the journal is particularly interested in the explanatory power of the articles that it publishes and it is hoped that the guidelines which follow will be useful to contributors.

The question *So What?* will be asked of every contribution, no matter how appealing the topic may be from an antiquarian standpoint. Because the value and significance of a research project are rarely self-evident, this question should be addressed explicitly by authors at the outset. It does not suffice to say that "little is known about this subject." Genuine significance may lie in clarifying complexities of human behavior by contrasting the evidence found in physical remains with the evidence found in written sources—for example, by comparing actual on-site procedures for an industrial process with ideal standards described in contemporary texts. Significance may lie in the presentation of practical advice for increasing public awareness of industrial sites—for example, by describing strategies for marshaling hobby groups on behalf of conservation and rehabilitation. Significance may lie in explaining the role, definition, or methodology of industrial archeology—for example, by analyzing specific professional conduct in light of legal developments in cultural resource management.

Finally, significance may lie in generalizing from specific evidence—for example, by examining a site in detail, establishing from corollary evidence that which is typical, and then drawing conclusions about non-surviving sites. This is perhaps the most perilous of all historical exercises. The basis for generalization must be confirmed convincingly. Too much must not be concluded from too little. In all cases, authors must deliver on their promises—establishing significance is not a matter of playing tricks with words.

Thus, manuscripts should be logical, built carefully on an explicitly stated thesis. Generalizations must be defended, arguments clearly explained. Authors are also asked to be sensitive to wordiness and the deadly pall of the passive voice. *The Elements of Style* by William Strunk, Jr., and E.B. White, and *The Practical Stylist* by Sheridan Baker are useful guides to clarity of expression and common grammatical mistakes.

Further details may be obtained by consulting past issues of *IA*, beginning with Volume 6 (1980), and the inside back cover of this issue. Submissions should be made in quadruplicate, each copy preceded by a 50 to 100-word abstract and separate title page, to facilitate the refereeing process. Double-space *everything*.

THE NORTON PRIZE

The Society for Industrial Archeology is pleased to announce that the Norton Company, Worcester, Massachusetts, has generously endowed a cash prize to be given to the author(s) of the outstanding scholarly article published in *IA* during the past three years. The Norton Prize is intended to encourage and recognize scholarship within the broad discipline of industrial archeology and will be awarded each year at the Society's annual meeting. Additional contributions to the prize fund should be sent to the Treasurer, SIA.

IA

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COVER: In 1890 the Page Belting Company of Concord, New Hampshire, developed light, double-ply leather power transmission belting to drive hydropowered dynamos. This rather overstated illustration of the company's products' role in providing power to operate industry and illuminate streets appeared in its 1894 catalogue. See Dennis E. Howe, "The Page Belting Company: A Study of 19th-Century Power Transmission Belting Manufacturing," pp. 5–20.

IA is published biannually by the Society for Industrial Archeology, Room 5014, NMAH, Smithsonian Institution, Washington, D.C. 20560 USA. Single copies of this issue: $10. *IA* and *SIA Newsletter* provided without additional charge to members. Membership in the SIA may be obtained by writing the Treasurer, c/o the address above. Membership classes and annual dues: Individual $35, Couple $40, Institutions $40, Contributing $60, Sustaining $125, Student $20.

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ISSN 0160-1040.

IA Editorial

The three articles in this issue are excellent representatives of the many different aspects of our field. Dennis Howe's article on the Page Belting Company is only the third we have published on the leather belting industry, and the first dealing with an actual manufacturer of belting. The Page Belting Company, which began production in 1867, is today one of the last manufacturers of leather transmission belting in the United States, and its products may be found in use throughout the country.

Emory Kemp's article examines the issue of national styles in engineering, specifically in Great Britain, France, and America; and he explores the early modern suspension bridge to make a convincing case for the presence of distinctively different styles in each of these countries. David Shayt, on the other hand, focuses on a single industrial survival—a piano key bleach house in the town of Deep River, Connecticut. This is virtually the last such bleach house to have survived, and Shayt has done a superb job of documenting the technology used in bleaching ivory piano keys. We are also extremely fortunate to be able to include a photo essay by William L. Taylor documenting the Brown Company of northern New Hampshire and Maine. Photo essays are always a welcome addition to our journal. We would be delighted to receive them in the future. Photos should be exhibition quality if possible.

With the appearance of Volume 19, *IA* is now just one year behind schedule, and all of us involved in the production of the journal are making every effort to get fully caught up by the end of 1994. It will not be easy because—in spite of the extremely diverse interests of our membership—we do not receive as many articles as we would like, and approximately one-half of all submissions do not clear the review process for one reason or another. That means we are always eager to receive many more manuscripts that are well-researched and of interest to a broad international audience. If you are one of those who is disappointed because the journal has fallen a bit behind schedule, I want to encourage you to submit an article to us for possible publication. We will get caught up *only* if our members do a lot more writing!

Finally, I wish to thank Donald C. Jackson of Lafayette College for his five years of service as Book Review Editor for *IA*. Don is officially "stepping down" to pursue other interests, but he has done an excellent job for us, and his column "Short Takes" has been a very important addition to this journal. He will be greatly missed.

David R. Starbuck

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The Page Belting Company: A Study of 19th-Century Power Transmission Belting Manufacturing

Dennis E. Howe

The process for manufacturing flat leather power transmission belting during the last half of the 19th century has been synthesized using historic photographs, rediscovered documents, and company publications, and by observing the modern methods of the Page Belting Company of Concord, New Hampshire. A review of the general concepts of power belting specifications and industrial applications is given.

Introduction

Throughout the 19th century and for much of the 20th, nearly all of American industry was moved on the backs of cattle. Not literally of course, but rather, it was flat leather belting manufactured from steer hide that transmitted industry's power. The loom, the lathe, the drop forge, the saw—virtually all machines received their motion and energy from a series of endless flat leather belts and pulleys connecting them to a water turbine, steam engine, or electric motor. There was a time when one "could scarcely glance into a shop or factory of any description without encountering a mass of belts which seem at first sight to monopolize every nook in the building and leave no room for anything else."[1] Figures 1 and 2 illustrate such scenes.

The unique characteristics of flat leather belting contributed to the great success of industries for a hundred years. But as the 20th century comes to a close, the use of flat leather power transmission belting has nearly been abandoned. The smooth-running ribbons of polished steer hide that conducted power from spinning ceiling-mounted shafting to each machine have been replaced with innocuous electric cables, and the technology of belting manufacture, together with the knowledge for its efficient utilization, face extinction. Considering the critical role of leather belting in industrial history, one may wonder why so little attention is being paid to it by modern researchers.

Perhaps the reason that leather power transmission belting has escaped serious IA study was given by William Worthington, Jr., when he wrote, "the drive belt often goes unnoticed or is quickly dismissed because of its apparent simplicity."[2] As is the case for so many devices whose genius of design resulted in a dependability that became commonplace, the "simplicity" of leather belting is a deception. The manufacture of predictable and reliable transmission belting from the stretchy, irregular, seemingly inappropriate hides of cattle helped assure the success of the great mills of the 1800s. Its development required invention, sound engineering, craftsmanship, and effective communication between belting manufacturers and the millwrights who would apply it.

The Page Belting Company of Concord, New Hampshire, which began production of leather power belting in 1867, is one of only a handful of firms in the United States that have continued to manufacture leather power transmission belting.[3] This article presents an interpretation of the process of manufacturing leather belting applied during the last quarter of the 19th century when nearly all of industry was dependent on it to transmit power to machines. The research represents a small part of a larger in-progress study of the Page Belting Company which is intended to document its technological contributions to belting development, the architecture of its mill buildings, its social history, and its relationship to the greater industry. Interestingly, the Page Company has continued to apply many of the same processes, tools, and machines it has used since the 19th century. Photographs, company documents, and the testimony of employees suggest that, while the preparation of leather for belting (called currying) has undergone much change since the 1800s, little has changed in the way endless belting is manufactured from it.

During its developing years (1866 to 1890), Page patented new tanning processes, perfected leather currying techniques, developed patented belting for a wide range of different applications, and invented specialized tools and machines for the manufacture of belting. In that period the company became an important component of a major industry that progressed from a dependence on trial-and-error methods to one that applied well-understood engineering processes. During those years, typical of the great industrial development of the time, much scientific research of leather power belting was conducted, and standards for its manufacture and application became well established.[4]

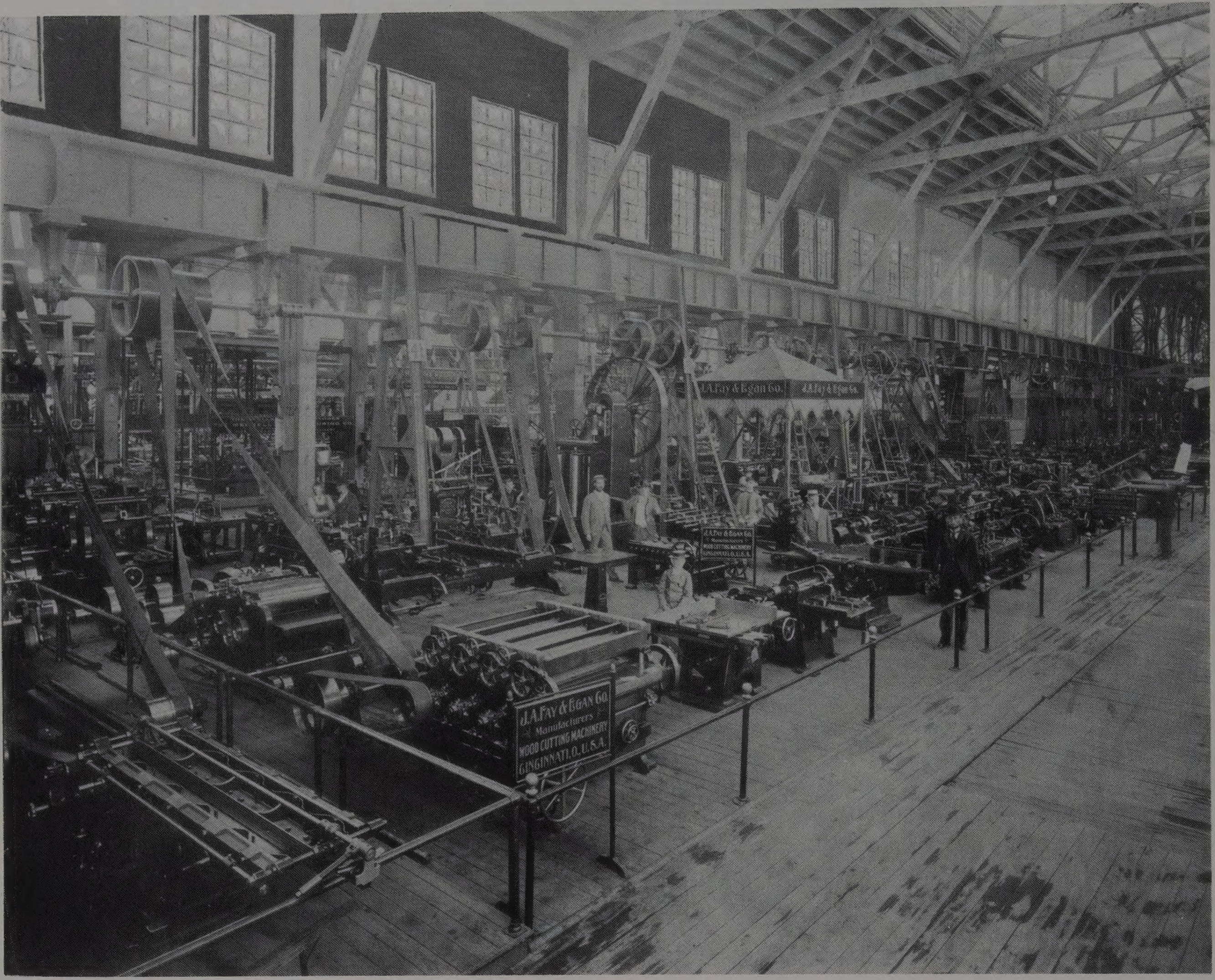

J.A.Fay & Egan Co.
J.A.Fay & Egan Co. Manufacturers Wood Cutting Machinery Cincinnati, O. U.S.A.

Figure 1. *Woodworking machinery manufactured by the J. A. Fay & Egan Company of Cincinnati is demonstrated at the 1893 World's Columbian Exposition in Chicago using Page Belting Company's leather power transmission belting products.* Page Belting Company photo.

Theodore Z. Penn researched some early New England leather belting applications and noted that historically little attention was paid to documenting such use. While power transmission through pulleys and endless belting is an ancient concept, the earliest manufacturing mills with central shafting were designed to be powered through iron gear transmission systems. Mills built with centralized gearing systems were short-lived, however. Vibration, noise, and other problems caused millwrights to look to leather belting to supply power from the prime mover to the individual machine.[5]

While it is beyond the scope of this article to attempt to trace the origins of the transmission of power with endless belting, a cursory review of the literature suggests that the general application of leather drive belts began early in the 19th century. Oliver Evans did not illustrate or describe belt power drives in his mill designs in *The Young Mill-Wright & Miller's Guide* (1795), although he demonstrated his knowledge of physics and his competence with the mechanics of pulley systems that are the foundations of such designs. He utilized endless leather elevator (or conveyor) belts frequently in his mills.[6] Thomas Blanchard's lathes, however, dating to the 1820s, were designed with leather power transmission belting.[7] By the time of the Civil War, the transmission of power from the main power source to the individual machines via centralized shafting and leather belts was the norm, and was applied to mills of every type.

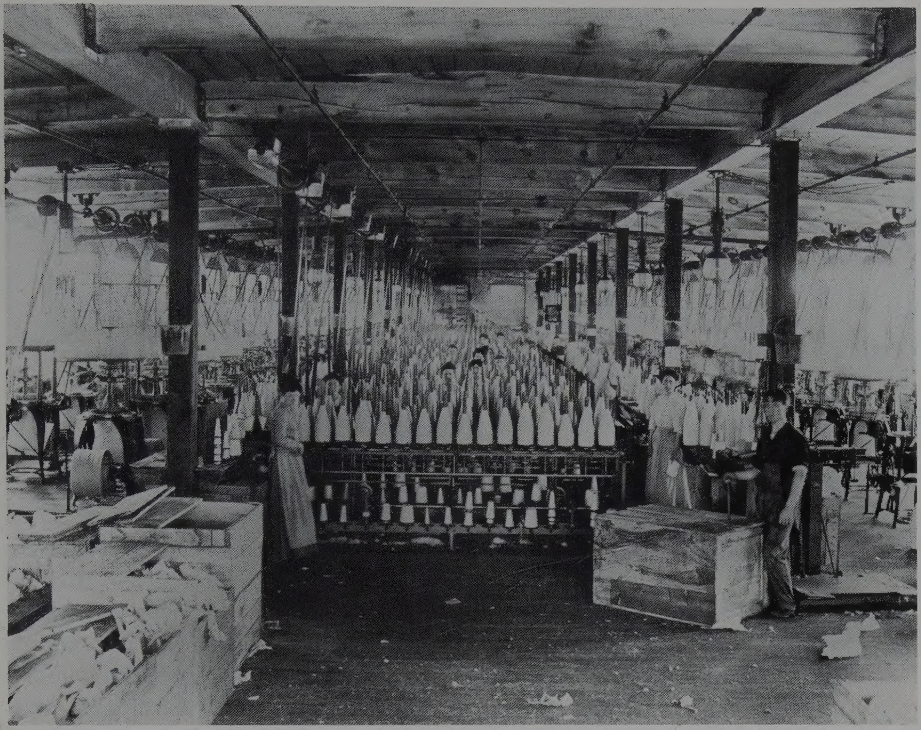


Figure 2. *A spinning room of the Amoskeag Manufacturing Company, Manchester, New Hampshire, c1890, where a myriad of leather belts provide power to the spinning machines.* Photo courtesy of the New Hampshire Historical Society.

Typically, power belting used in each mill was purchased locally from small, nearby tanners.[8] One of those local tanners was Moses Page, who held a patent, issued May 8, 1866, on a process for manufacturing improved lace leather. The same process also produced stronger, more flexible belting leather, and he began to manufacture power belting in a shop rented from the Amoskeag Corporation on Mechanics Row in Manchester, New Hampshire (figure 3). Young Charles and George Page bought their father Moses's business in 1869 and moved it to larger quarters in Franklin. The products quickly became widely known, the business grew, and the Pages admitted a number of investors. The Page Belting Company was organized under the laws of the State of New Hampshire on August 3, 1871, and a charter was granted on July 4, 1872.[9]

With George Page in charge, the company continued to grow rapidly, and it purchased a tannery, owned by Ebenezer and Edwin Wallace, located near Horse Shoe Pond on Commercial Street in Concord and moved the machinery from Franklin. The Wallaces were made officers of the Page Belting Company, and the tannery was soon enlarged with the addition of a curry shop.

Shares of stock were sold periodically to raise capital, and sales offices were opened in Boston, New York, Chicago, and San Francisco. In 1878, George Page went to Europe to open markets there. A new boiler- and enginehouse was constructed in 1882. According to Charles Page's history of the company, capital increased from $75,000 in 1872 to $500,000 in 1892. Aggressive marketing used printed advertisements (such as shown in figure 4) and took advantage

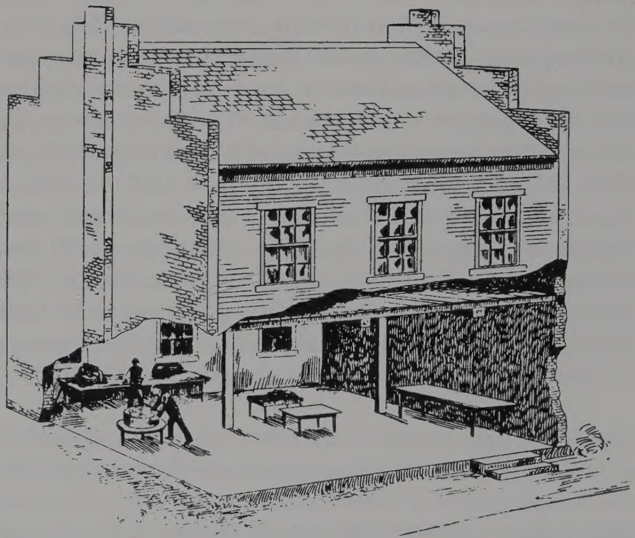


Figure 3. *A cutaway view of Page Belting Company's first belt shop (c1868) which was published in 1893 to commemorate the company's 25th anniversary.* Courtesy Page Belting Company.

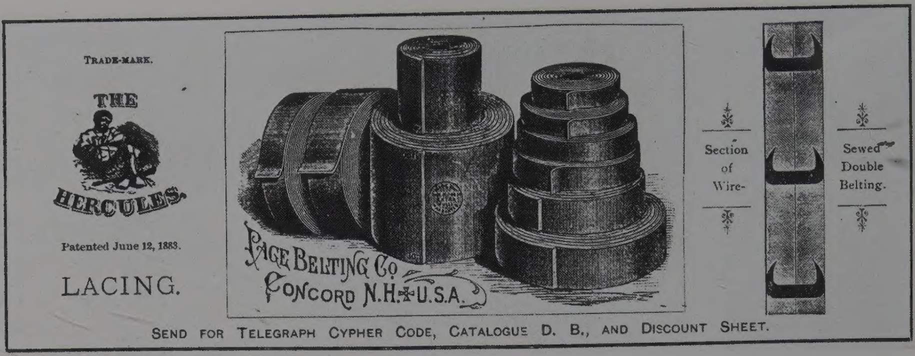

TRADE-MARK.
THE HERCULES.
Patented June 12, 1883.
LACING.
PAGE BELTING CO
CONCORD N.H. U.S.A.
Section of Wire-
Sewed Double Belting.
SEND FOR TELEGRAPH CYPHER CODE, CATALOGUE D. B., AND DISCOUNT SHEET.

Figure 4. *A Page advertisement appearing in Ladd's Discount Book, published by Sargent & Company, New York (c1887).*

of opportunities to exhibit Page's products to large crowds of people, for example, at the 1876 Centennial Exhibition in Philadelphia and the 1893 World's Columbian Exposition in Chicago.[10] The company even produced stereoscopic views of its products.

During 1892 and 1893 two new brick buildings were constructed: a four-story curry shop (84 feet long by 50 feet wide) and a three-story belt shop (260 feet long by 54 feet wide) (see figure 5). According to the company's 1894 product catalogue, "These new buildings were built upon the most improved plans of mills construction. They were provided with electric motors, lighted by electricity, and furnished with the best known methods of protection against fire. The complete works contain 173,353 square feet of floors." (The tannery was completely destroyed by fire in 1894 and was not rebuilt.) During 1906–1907 the boilerhouse was rebuilt and fitted with a new boiler and other equipment. Also during that time a 200-foot by 50-foot three-story addition to the curry shop, a storehouse (130 feet by 48 feet), and an office building (104 feet by 40 feet) were constructed.[11] All of the buildings (save the tannery) constructed between 1892 and 1907 were extant in 1993.

During the final quarter of the 19th century, the economics of mill and factory designs translated into demands by users that manufacturers of leather power transmission belting not only produce reliable products, but also provide technical application information to their customers. During most of the 19th century, the purchase and installation of belting had been based on empirical knowledge. Millwrights called on their own experience and various "millwright's rules" to determine the size of belt for a given application. One writer reported that, for the quality of belting being produced, belt loading practices of the 1880s were severe.[12] Overloading presented a hazard to workers and was troublesome to millwrights, causing frequent shutdowns to "take-up" stretched belts.

Many researchers were addressing the problems of belt failure.[13] On May 1, 1885, J. Howard Cromwell wrote in the preface to his *Treatise on Belts and Pulleys:* "Strange as it may seem, it is nevertheless true, that there is scarcely a machine-shop in America which can definitely and correctly calculate the proper width of a leather belt which will safely transmit a given horsepower." Cromwell wrote letters to many belt manufacturers and users asking for specific information such as coefficients of friction, tensile strength, and rules and formulas for estimating the horsepower ratings of belts. He reported that "not a single one [could provide] any definite information." He also reviewed the contemporary literature being used by the mechanics for application formulas. He made the calculations recommended by each of five different authors and demonstrated five different results with a range of 233 percent.[14]

The effect Cromwell's criticism and treatise had on belting manufacturers probably cannot be weighed directly because he was reflecting the concerns of many engineers of the time. However, much was accomplished during the last half of the 1880s as inferred by the activities of Page Belting Company. On November 29, 1887, the company patented a "belt testing and stretching machine" and in the company's sales literature much was made of stretching, testing, and "running-in" belts before shipment (see figure 6). The company also developed belting for specific environmental applications such as electric dynamo drives. The company's 1894 product catalogue devoted more than a third of its 96 pages to technical application information.[15]

Demonstrating an awareness of technological innovations that might either affect their market or contribute to the improved efficiency of their manufacturing, the Page brothers formed the Concord Land & Water Power Company in 1892 and developed Sewall's Falls on the Merrimack River, three miles north of their plant, into an electric hydropower facility.[16] Their purpose was to provide three-phase

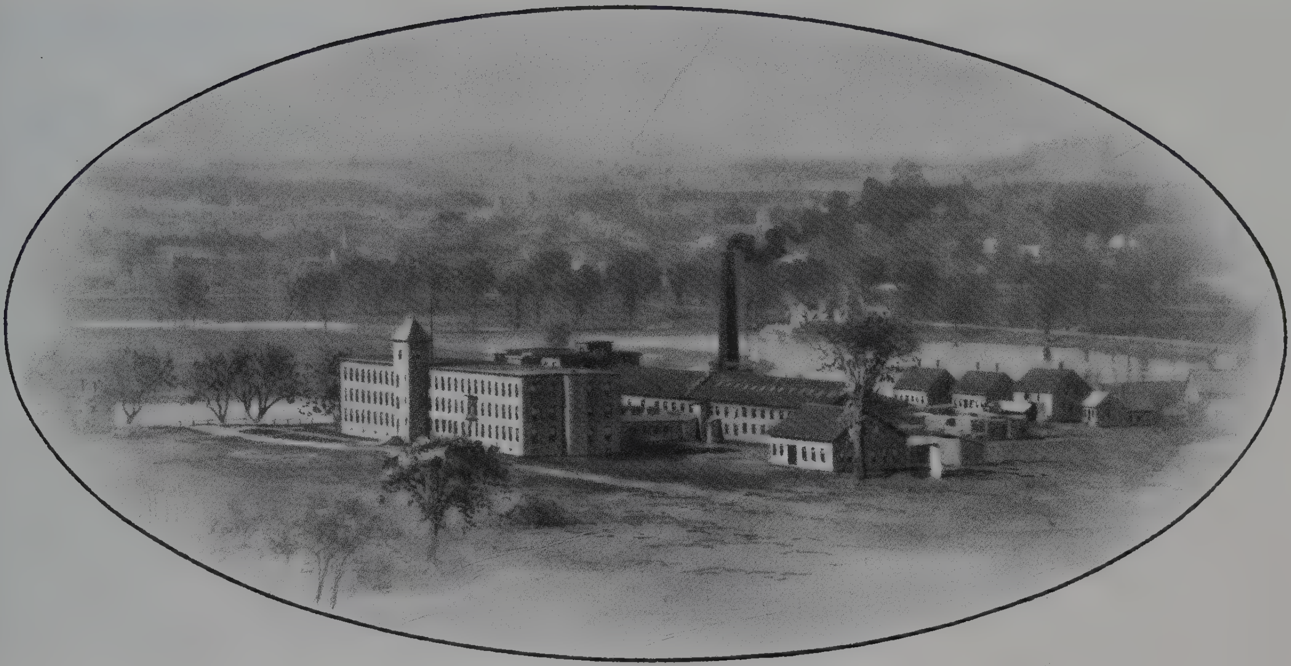


Figure 5. *The Page Belting Company plant (c1894) in Concord, New Hampshire. The belt shop is the building with the tower in the foreground; the curry shop is behind it.* Page Belting Company photo.

electric power to their belting plant in which they installed the first General Electric Company three-phase induction motors which would drive the central shafting.[17]

The Page company also broadened its product lines and began manufacturing round leather belting after purchasing the Manhattan Leather Belting Company of New York City in 1896. The ability to manufacture round belting permitted Page to enter into a contract with Singer Sewing Machine Company and produce millions of feet for treadle sewing machines.[18] The development of link belting that was patented by George Page in 1889 was an especially clever addition to the product line, since it not only provided exceptionally strong waterproof main-drive belting that could be quickly and easily adjusted for length, but also utilized innumerable small pieces of leather that might otherwise have been wasted in the manufacture of flat belting. Irregular pieces of trimmed leather were die-cut to produce links that were joined with steel rods to construct a drive belt in a configuration resembling a boot-wiping mat (see figure 7).

The belting of rubber-impregnated textiles was also added to the product line, as were a number of splicing, repair, and dressing materials. The company diversified to augment its leather belting with such new products as leather hydraulic and pneumatic packings.[19]

But power belting remained the company's major product. Its standard product line included a range of grades and sizes from 1 inch wide to 15 inches wide; single, double, and triple ply; heavy-duty, waterproof, planer (slotted), and dynamo.[20] It also manufactured special-order main-drive belts of great sizes such as shown in figure 8. A three-ply belt, 102 inches wide, weighing 5,176 pounds, was illustrated by a c1893 photograph, shown as figure 9, and the 1894 catalogue illustrated tandem, 72-inch and 71-inch, three-ply main-drive belts demonstrated under full load at the 1893 Chicago exposition.

Belting Manufacture

The manufacturing of belting, while aided by machines, was, and continues to be, accomplished by hand by craftsmen. Using historical documents and an extraordinary collection of contemporary photographs, together with observing "modern" belt production, it is possible to synthesize a description of the belting manufacturing process of the late 19th century.

Leather that was to be made into power belting needed a surface suppleness in order to grip a pulley without slipping, but also a certain amount of rigidity to prevent curling at

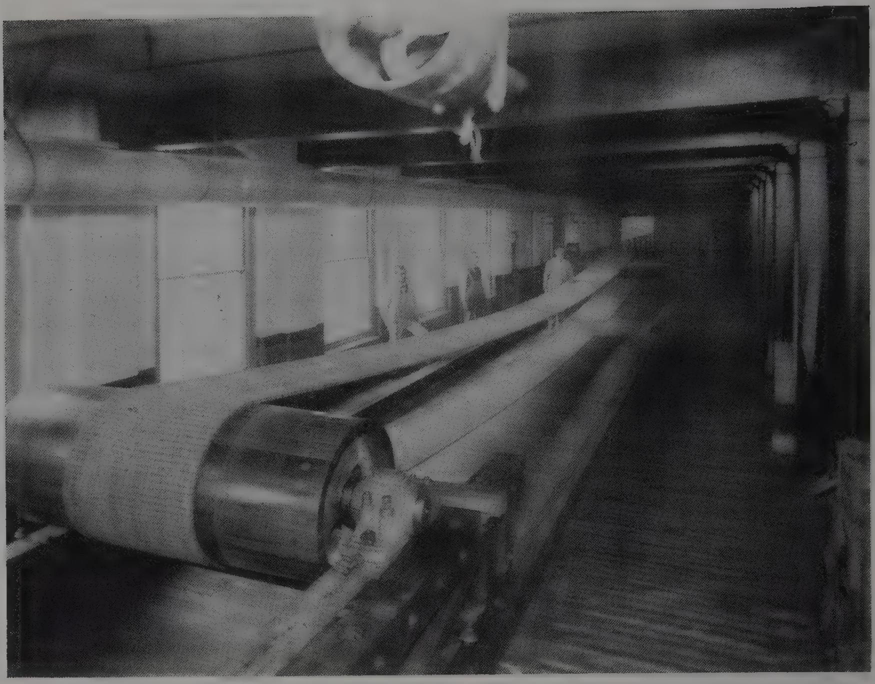


Figure 6. *A 30-inch-wide Acme link belt mounted on the pulleys of a "mammoth testing and stretching machine" in preparation for a running test before shipment to a customer, 1893. This photo is typical of many in the Page Belting Company collection which were used in advertising and served to emphasize the attention paid to pre-stretching belting before it left the belt shop.* Page Belting Company photo.

the edges or twisting and waving while running at high speed. A high tensile strength was required to pull a heavy load without breaking, along with flexibility without stretching. The effects of heat or moisture had to be minimal.[21] It was the job of the skilled currier and his curry shop staff to impart these seemingly conflicting characteristics into power belting leathers.

The tanning process applied agents that converted the raw collagen fibers of a hide into a stable product no longer susceptible to putrefaction. The process and chemistry of tanning is beyond the scope of this article, except to note that 19th-century power belt leathers were produced by vegetable—or "oak"—tanning.

There is great variation in the thickness, tensile strength, elasticity, and texture (or grain) of the hide of an entire steer, even after tanning. The portion best suited for belting was an area of the back between the front shoulders and the base of the tail; extending part way down the sides, it was called a "butt." Here the hide was thickest and had the fewest natural wrinkles. Each half of a butt (from a line along the spine downward) was called a "bend." Within a high-quality butt there were zones with different physical properties. The area along the spine (the "center stock") had tightly knit, short fiber with the lowest stretchability and was best suited to main power drive belt applications. The "kidney" pieces on the sides were the thickest leather with

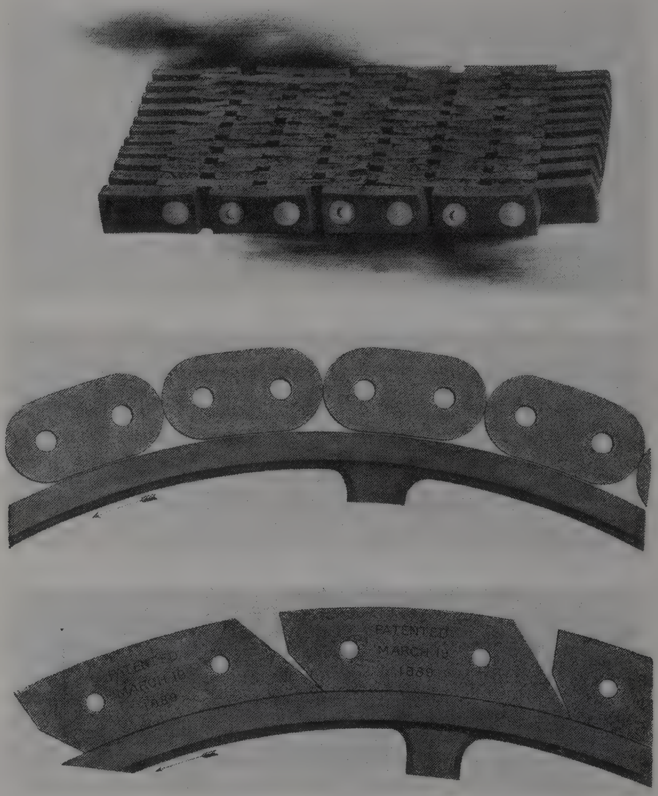


Figure 7. *A section of Acme link belting and two types of links as illustrated by the Page Belting Company 1894 product catalogue.*

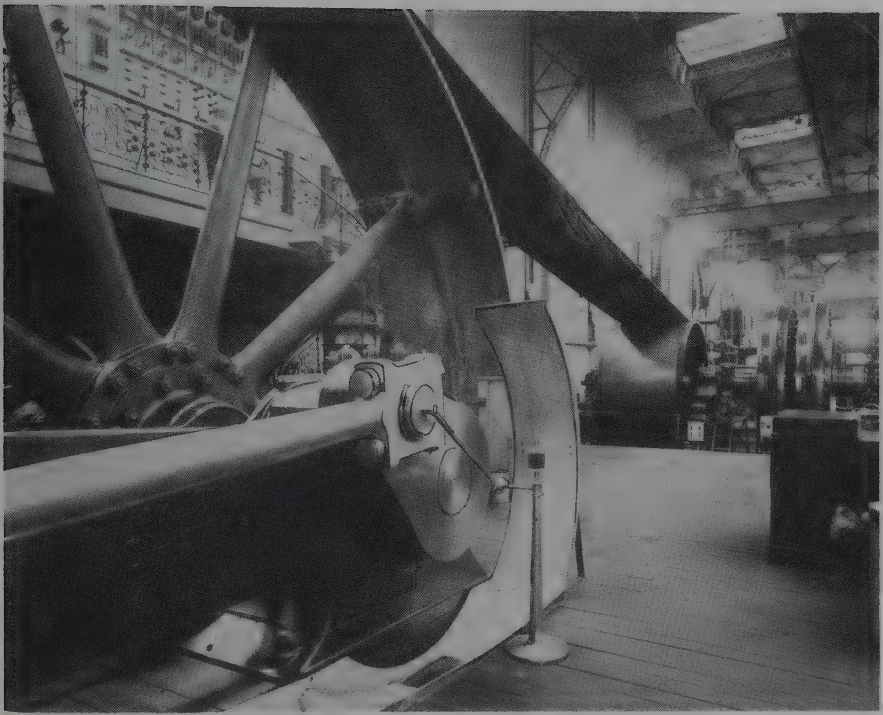


Figure 8. *A huge main-power-drive belt manufactured by the Page Belting Company demonstrated at the 1893 World's Columbian Exposition in Chicago.* Page Belting Company photo.

tightly knit, long fiber having good elasticity. The "belly" pieces (or side stock) exhibited the longest, loosest-knit fibers with high tensile strength. A belting butt was roughly square with dimensions ranging from 44 to 52 inches on a side (see figure 10).

A newly tanned butt was harsh and stiff, and needed to be subjected to a process of "fleshing," "scouring," "stuffing," and other finishing in the curry shop to impart the desired qualities. Excess flesh (loose material on the inside of the bend) was removed with a fleshing machine containing a fluted herringbone roller with sharp steel blades. Considerable strength and skill were required of the fleshing machine operator as the machine's arm with its rotating blade assembly alternately moved forward toward the operator, then drew back over the inside of the bend which the operator positioned and held. Fleshing was not meant to reduce the thickness of the bend, only to remove non-skin materials that may have remained after tanning and that did not provide any desirable attributes to the bend.

In the scouring operation, unwanted tanning residue carried in the bends was removed by soaking them in vats and later washing them in large wooden rotating drums. The currier determined the time, temperatures, and process sequences for the removal of unwanted substances almost entirely from his experience and skill. He also added oils and other fatty animal and vegetable substances to the bends in a "fatliquor" that was introduced as they were turned in the wooden drums. The bends that were finally removed from the drums at the end of this process were a wet mass, hardly resembling leather, which needed to be dried with heated air (figure 11).

After drying to the appropriate point (moderately damp), the bends were "stuffed." This procedure added and diffused grease thoroughly throughout the fibers of the bends. Like most operations in the manufacturing process, it was accomplished by hand (although a machine had been used in the mid-1870s, it was soon abandoned). Various tallows, oils, and waxes (all fish, animal, or vegetable derivatives) were applied to the bends to impart flexibility and moisture resistance. Stuffing added 10 to 15 percent to the weight of the bend and contributed to long belting life. At the end of the stuffing process the bend was further dried to a slightly damp, or "sammied," condition, and was "set out" as its grain surface was worked by hand, imparting a firmness.

After they were stuffed and set out, the bends were stretched, a critical step in the currying of belting leather. Some bends were clamped into powerful stretching machines, placed under great tension for an unknown (but relatively short) length of time (figure 12), and then moved to the press room

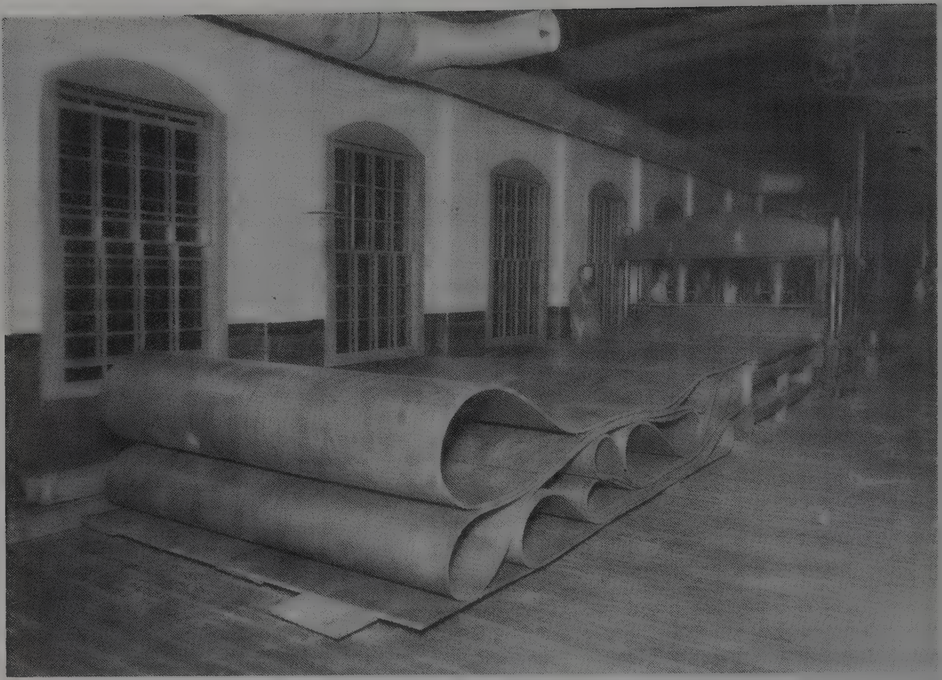


Figure 9. *A three-ply "exposition" belt, 102 inches wide and 203 feet long, being constructed c1893 using a large hydraulic press producing a pressure of 700,000 pounds. This belt weighed 5,176.5 pounds.* Page Belting Company photo.

where they were alternately stacked with wide boards and pressed flat for an extended period (figure 13). Other sammied bends were clamped into sturdy cast-iron stretching frames with fixed jaws on one side and a series of independently adjustable jaws at the opposite side. Skilled workers took up tension on the adjustable jaws, stretching the butt to its fullest extent (with a tension that varied with each zone). Care was taken to limit the tension so as not to rupture the fibers. Belting made from understretched bends would become excessively elongated after installation and cause a problem for the millwright as slippage on the pulleys increased. The tension applied to the various zones of the bend during the stretching operation varied with the physical properties of each as described earlier. The backbone section, for example, was stretched less than the kidney section. The bend was allowed to dry in tension on the stretching frame. The use of an early version of the stretching frame is illustrated by figure 14. After surface finishing as illustrated by figure 15, the bend was transported to the belt shop, and cut into strips to be assembled into belts (figure 16).

Leather power transmission belts were built by experienced belt makers who understood the physics of their application and the properties of the leather. The ideal belt was uniform in thickness, elasticity, and surface grain, perfectly straight and flat, and balanced. The belting craftsman knew very well that a bend varied in elasticity, stretchability, thickness,

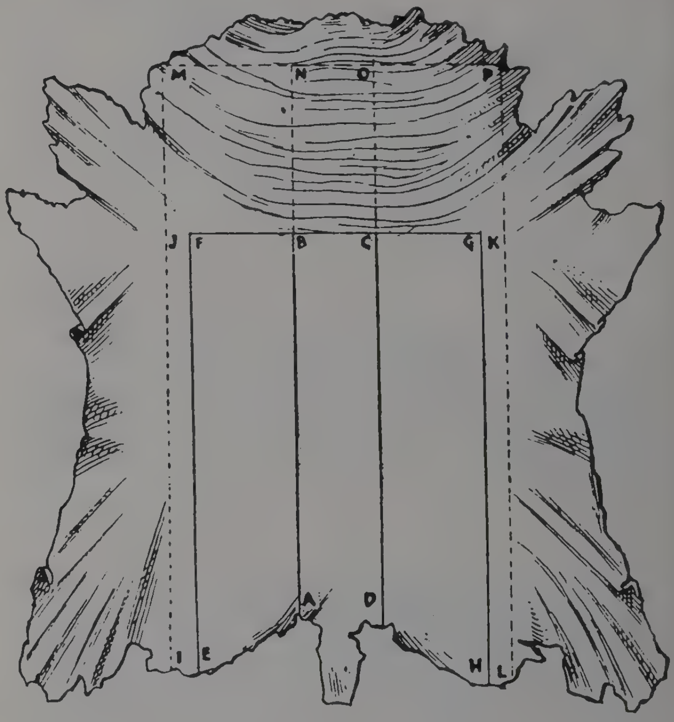


Figure 10. *An illustration originally published in the Page Belting Company's 1894 product catalogue showing the location of a belting butt in a steer hide. The best power belting grades are found in area ABCD (center stock), and areas AEFB and DCGH (kidney stock).*

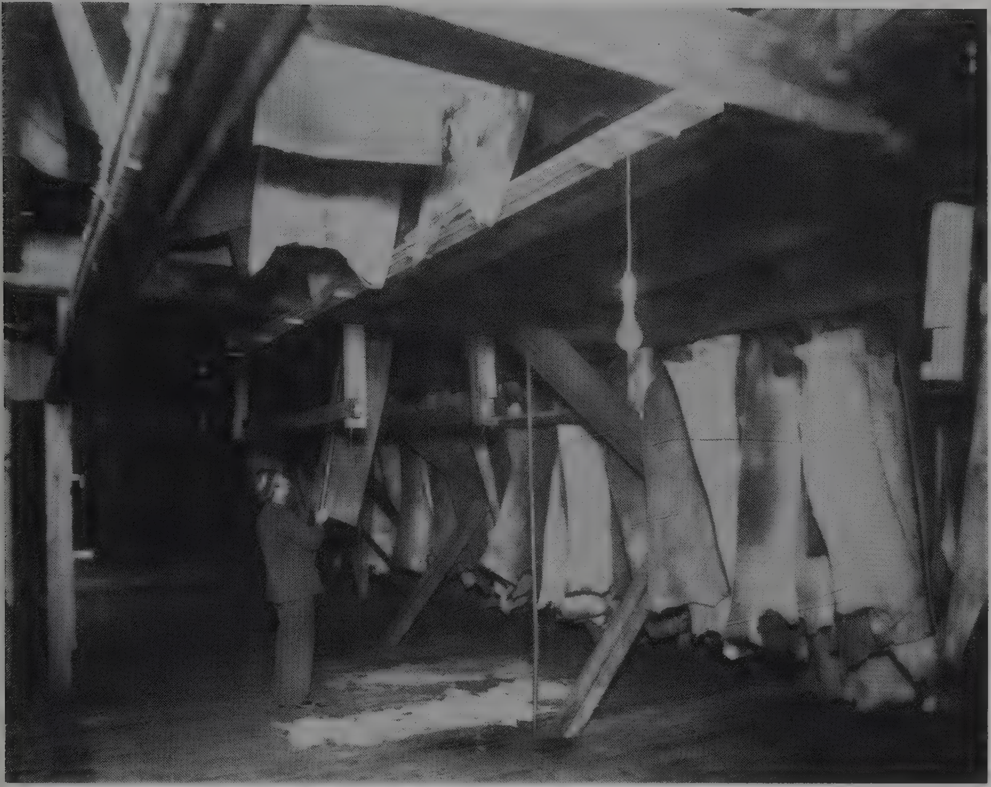


Figure 11. *Curried belting leather bends (a bend is half a butt) being air dried, c1893*. Page Belting Company photo.

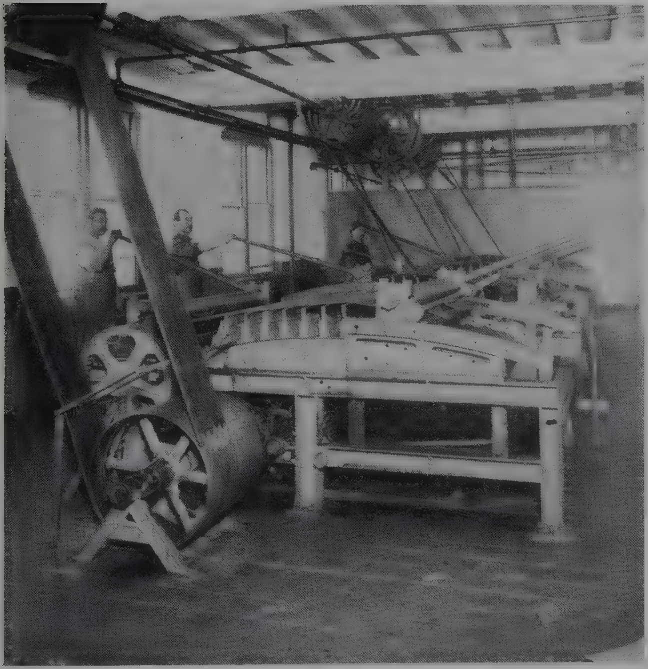


Figure 12. *Patented power leather stretching machines in the curry shop, c1893*. Page Belting Company photo.

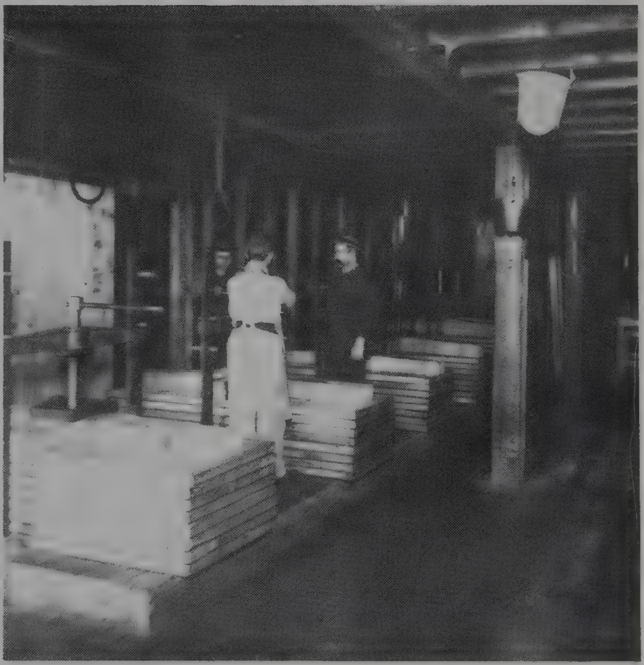


Figure 13. *The press room in the curry shop, c1893. Leather was compressed after being subjected to the power stretchers illustrated in figure 12*. Page Belting Company photo.

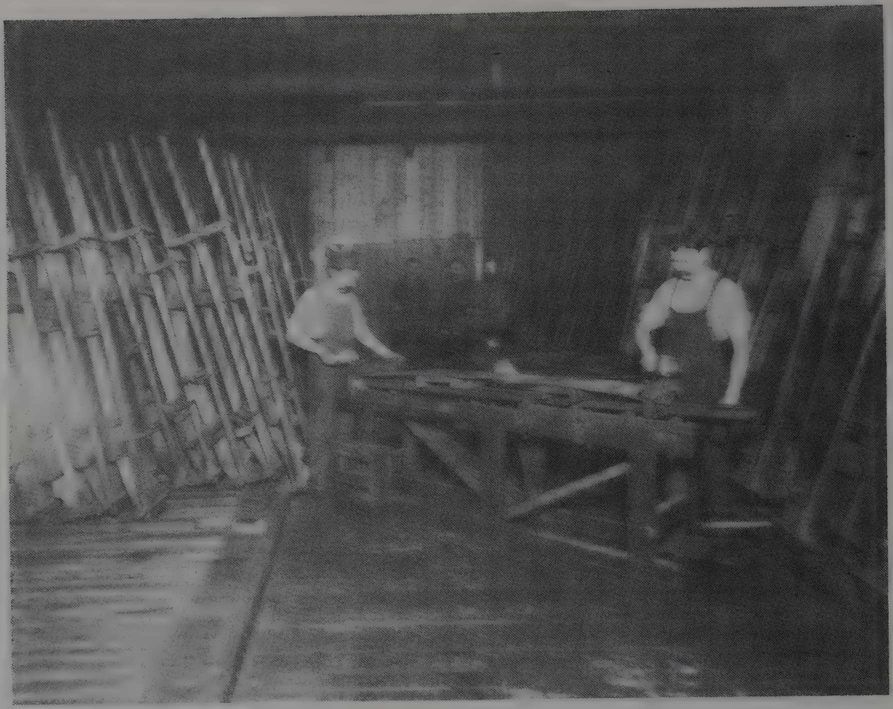


Figure 14. *A second stretching operation in which damp leather strips are clamped into cast-iron frames and left to dry under tension, c1893*. Page Belting Company photo.

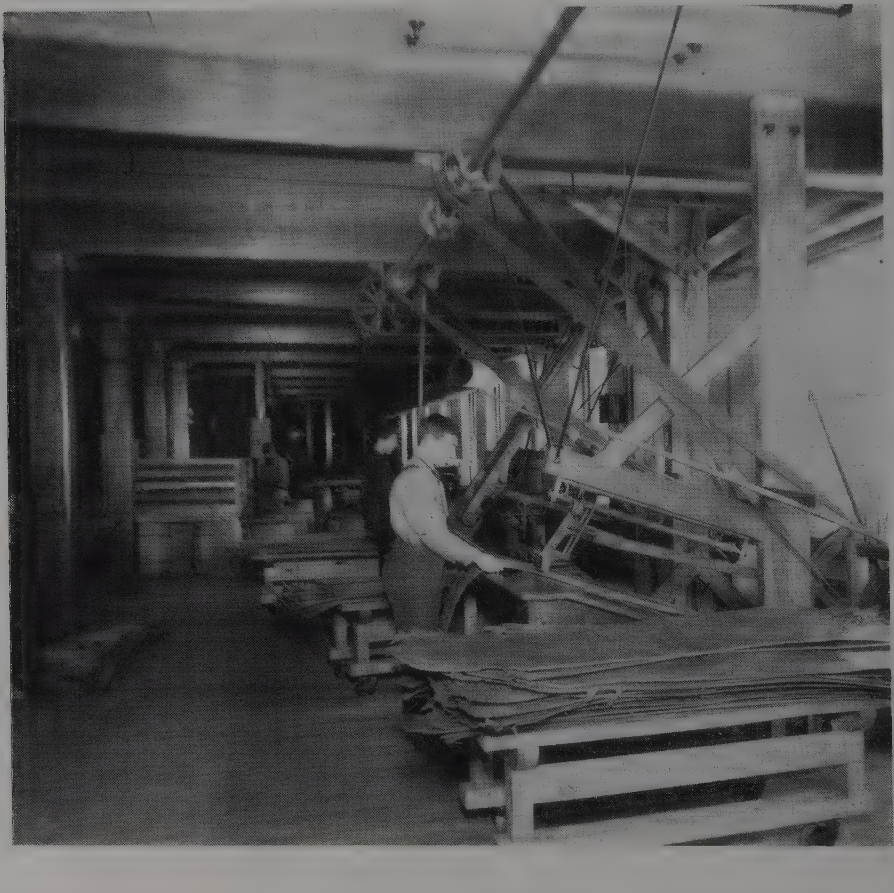


Figure 15. *Finishing machines work the surface of bends in a final curry shop operation, c1893*. Page Belting Company photo.

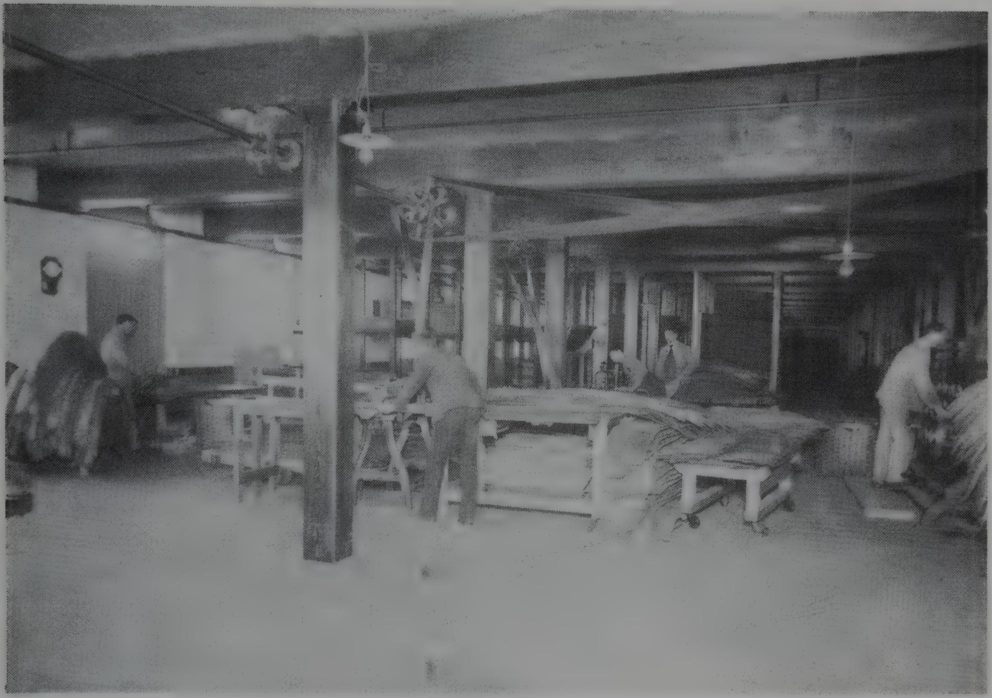


Figure 16. *The cutting room in the belt shop where bends are cut into belting strips and sorted for thickness, c1893*. Page Belting Company photo.

and grain direction in its different zones. A leather strip cut from a bend was straighter on the side originating closest to the backbone and stretched more on the side that had been closest to the belly, even when the best of currying was accomplished. In building a belt, the leather strips were applied so the negative consequences of such attributes as left and right curvature of the grain and variations in elasticity tended to cancel one another.

A belt maker selected strips of bends that had been sorted for left or right side, thickness, and the area of origin in the bend. He "scarfed," "pointed," and "scratched" the ends of each selected strip. (A splitting and scarfing machine for very wide belting is illustrated by figure 17.) That is, he tapered, squared, and roughened the ends so that a four-inch-long overlap splice could be made and glued.

The simplest single-ply belt was perhaps the most difficult to build. Compensation for side-to-side differences in the leather was accomplished by selecting strips with opposing characteristics, such as matching sections cut from right-side bends and left-side bends. The strips with alternating characteristics were lapped and glued end-to-end to form the belt. Care was taken to use strips of uniform thickness. While it was possible to split leather to a uniform thickness (which was commonly done with garment leathers), splitting was seldom done with belting leather because the piece would become too weakened by removal of the flesh side containing the strongest fibers. It was traditional that the grain-side surface was in contact with the pulley in American installations, therefore splitting to achieve a uniform thickness would have severely weakened a belting strip.

Cement used to secure 19th-century belting laps and plies was a hide or animal glue, softened with heat and water, which was applied to the surfaces and clamped in a hydraulic press for about one hour (figure 18). When a waterproof flat belt was constructed, cellulose cement was used. The cellulose was dissolved in a volatile solvent and applied in several coats, then clamped in the hydraulic press for a period of time much longer than required for hide glue—up to 12 hours. Double-ply belting was sewn with copper wire as illustrated by figure 19.

When absolutely waterproof belting was required in an application, Page recommended link belting because no glue was used in its construction. Link belting was well suited for heavy-duty, main-drive installations. It was constructed of small leather "links" which had been die-cut scraps unusable in flat belting (figure 20). The links were assembled with high-grade steel nail-like pins to form a long "doormat" configuration (figure 7). They were cut from strips and pieces that could not have been used for flat belting because they were either too small or contained a flaw that could be avoided in die-cutting. Link belts were constructed entirely by hand by threading the steel rods through the holes in the links. The assembled belt was smoothed on a drum sander to eliminate bumps and burrs that would prevent full contact with pulleys (figure 21).

Finished flat belting was trimmed at a uniform width and embossed with a trademark every 10 feet. It was also marked with an arrow indicating the proper running direction that best utilized the grain of the leather and avoided "peeling" the lap joints.

While many of the modern processes that prepare the leather and produce power belting are similar to those applied in the 19th century, there are some significant differences. The most important is that belting butts are no longer manufactured by tanneries. Instead, that portion of the steer hide that might have become a belting butt in the 1800s now becomes shoe sole leather containing stiffeners such as salt and sugar. These undesirable additives are removed in the curry shop using processes that comply with current environmental concerns. The result of the modern currying process is the same as that of the last century, producing leathers perfectly suited to belting, but at a higher cost than would otherwise be possible if belting leathers were available from modern tanneries.[22]

A second important difference in modern belt manufacturing is that the stretching and run-in procedures have been refined to eliminate unnecessary operations. Stretching by machine and pressing are no longer done, nor are dynamic run-in

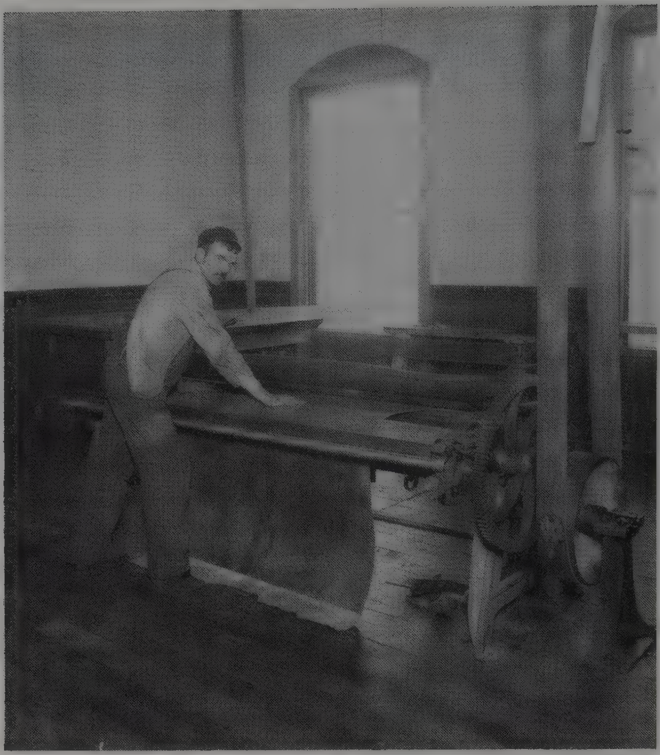


Figure 17. *A large splitting and scarfing machine in the belt shop, c1893.* Page Belting Company photo.

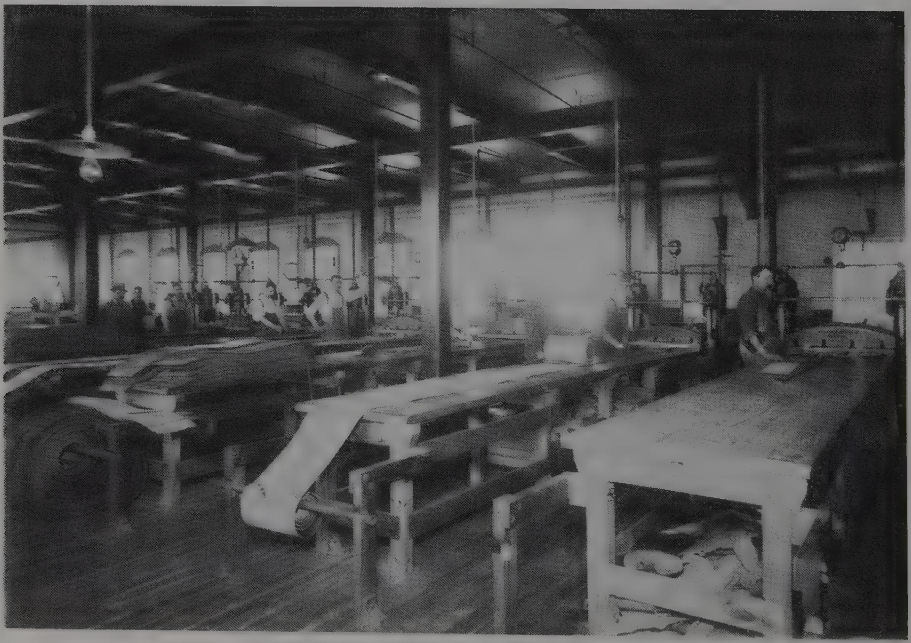


Figure 18. *A battery of work tables and hydraulic presses for assembling and gluing flat belting, c1893.* Page Belting Company photo.

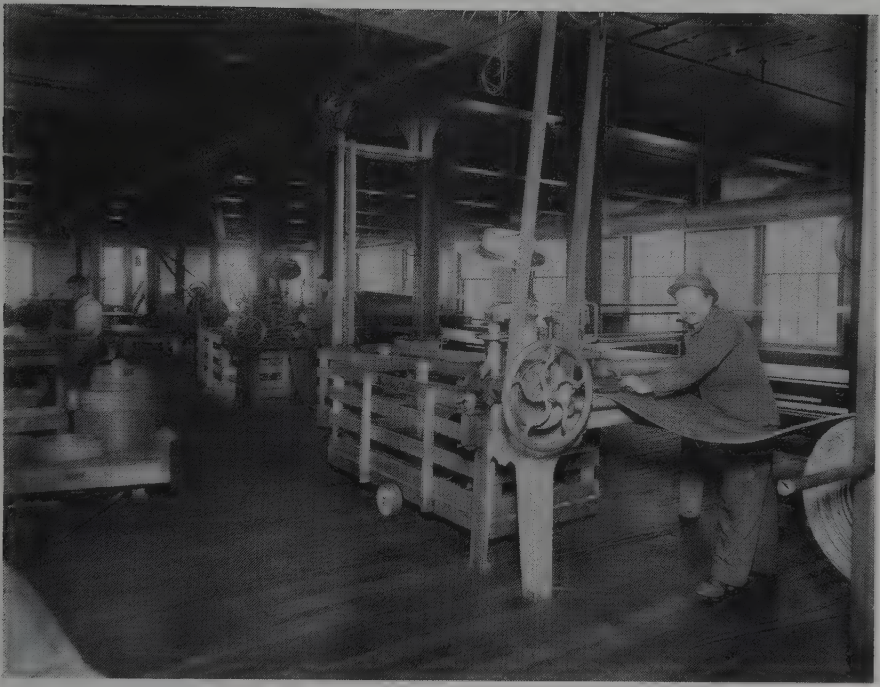


Figure 19. *A wire sewing machine in the belt shop finishing room, c1893. Belting that would be applied in damp environments where glues might fail was stitched with copper wire in such a way that the wire did not project above the surface (see the advertisement illustrated in figure 4).* Page Belting Company photo.

and stretching operations prior to shipment. The emphasis on stretching and run-in during the last century was perhaps more an activity that built customer confidence rather than adding materially to better product performance. Today, belting bends are simply stretched and dried on frames (the same frames constructed for the purpose in the 19th century). Modern cements are waterproof, and superior to the original hide glues once used in joints and plies.

Belting Applications

While serious researchers may find very detailed and technical belting applications information in a number of machinists' and engineers' handbooks and treatises,[23] it seems appropriate to consider some general concepts that help define the manufacturing process.

As general knowledge about belting increased among both users and manufacturers, loading and running speeds became better understood and it was possible to be specific about the kind of belting to be purchased. By the end of the 19th century, a customer needed to request more than "quality" belting; instead, written specifications of the belting were used to describe physical properties such as tensile strength, elasticity, elongation under stress, and moisture resistance. The earliest such specification to be located in the Page Belting Company's files was written by the Isthmian Canal Commission in 1911[24] (it stated that it superseded a specification written in 1909). Although it was brief (three pages), its standards were approximately the same as those later published by the U.S. Bureau of Standards in 1923.[25] While much research on the subject of the evolution of specifications has yet to be accomplished, it appears that the first specifications defining minimum standards had been set by purchasers soon after the publishing of the treatises on belting in the 1880s.

By submitting purchasing specifications to belting manufacturers that would produce belting with the defined characteristics, it was possible for mechanics and millwrights to apply belting that would provide predictable results. The specified belting could then be installed with some confidence by millwrights or mechanics who were concerned with operating power transmission systems at high efficiencies as they followed established guidelines for installation. Founded on the laws of physics, the guidelines set forth how best to adapt the properties of leather to the task of pulling loads. Before belting was purchased, however, care was needed to determine such factors as the power to be transmitted, fluctuations in power and loading, sizes and alignments of pulleys, operating velocities, and many other system parameters.

Installation guidelines were based on the ideal installation

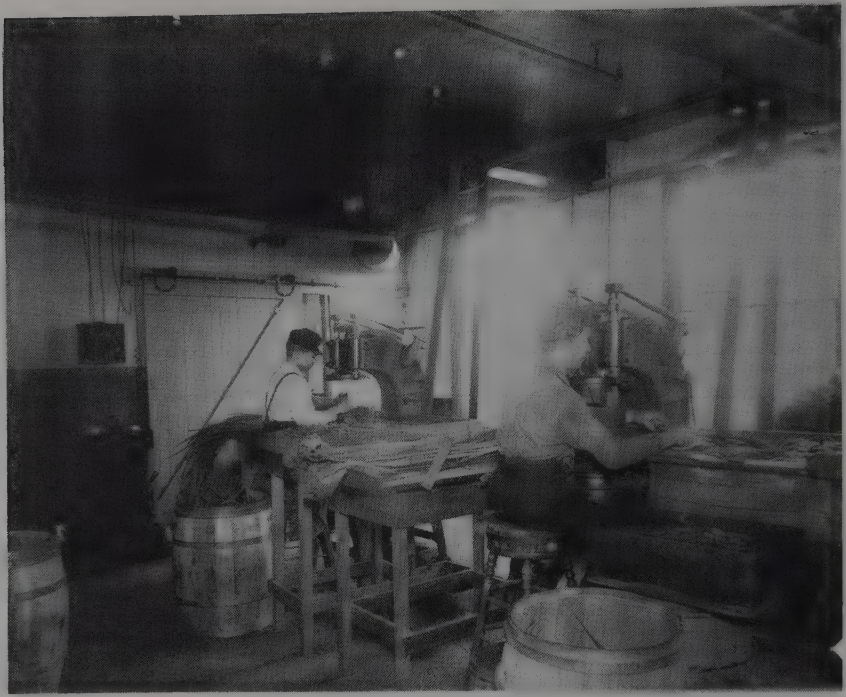


Figure 20. *Workmen using presses to die-cut small links from leather pieces which might otherwise have been scrap, c1893. (Figure 21 illustrates the finished links.)* Page Belting Company photo.

of leather power transmission belting and would have long distances between pulleys positioned in a horizontal plane. In the ideal installation, pulleys would never be positioned so that the belt ran in a vertical plane. Also, ideally, tension was applied to the bottom of the belting loop with the slack at the top. This took advantage of the weight of the belt on the slack side to increase tension on the pulleys and reduce slippage. Long horizontal belting loop installation actually took advantage of the elongation of the belt that resulted from normal stretching by increasing the belt's area of contact with the pulleys as the slack sag increased. In practice, the physical realities of the installation site and the need to conserve space prevented the ideal installation and compromises were made. Most machine drives were from ceiling to floor at a slope. Short belt drives often used an idler pulley in tension against the slack side to reduce slippage. Many schemes were developed to change direction of belting motion; to drive shafts on different axes such as horizontal to vertical, at angles such as 45 or 90 degrees; and to change shaft speeds. All of the effective schemes utilized techniques to maximize belting-to-pulley contact and to maintain adequate tension.

While the Page Belting Company's catalogues featured a variety of metal hooks and fasteners for connecting the ends of a belt, only two methods of making a belt "endless" were recommended. The foremost was splicing lapped tapered ends with a waterproof cement. The second was lacing with specially prepared leather or rawhide lacing. At the installation site, special clamps could be attached near the belt ends to be joined. The clamps were connected together with threaded rods or another device that could apply tension to the belting and hold the ends together for splicing. Several lacing schemes were used that would minimize the "bump" resulting from the thickness added by the lace. Often when new belting was installed, it was laced with a short set-in piece (with two laced joints resulting). The set-in piece was removed after a run-in period in which the belt was stretched. (Three- to seven-percent elongation could be expected.) After removal of the set-in piece, the belt could be spliced with a lapped and cemented joint.

The horsepower that a belt of a given cross-section could transmit was directly related to the speed at which it ran. The tension forces on a belt as it delivered greater horsepower required that its cross-section have adequate tensile strength. Since the maximum thickness of leather is limited, belting must be proportionately wider to successfully deliver greater horsepower. Logic would suggest that wide belts running at high speed would be the most efficient. This is not the case, however, because air becomes trapped between the belt and the pulley surfaces of wide belting running at high velocity. The trapped air cushion reduces friction, causing an increase in slippage.

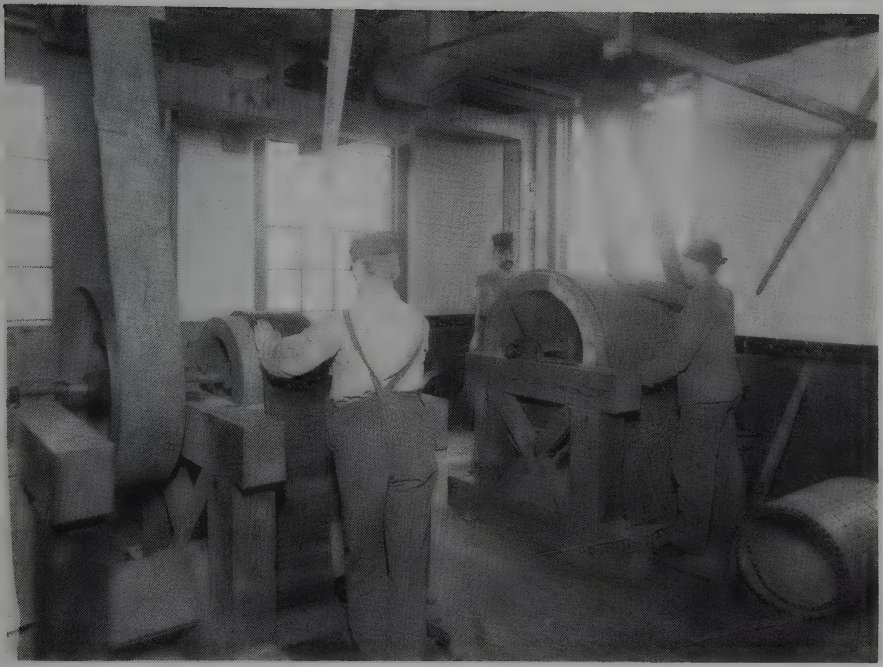


Figure 21. *Workmen smoothing the surface of Acme link belting on drum sanders, c1893.* Page Belting Company photo.

The Page Belting Company produced two kinds of belting for high-velocity applications such as driving electric dynamos and wood planers that must run at high speeds for smooth cutting. In the Page "Eureka Dynamo Belting," slots were punched near the center line of belting, thus allowing air trapped against the pulley to escape. The "Acme Link Belts," which were very strong and could pull very heavy loads, also permitted trapped air to escape through the gaps between links.

The record of the Page Belting Company demonstrates that during the final quarter of the 19th century a great effort and substantial resources were invested in improving leather's ability to transmit power to industry's machines. The endeavor was successful, and the company flourished. But the usefulness of leather power transmission belting reached its peak with the first quarter of the 20th century as it became the "electric power" century. In time, each machine, having its own electric motor as its source of movement, would "plug into" an electrical outlet. Short leather belts helped to adapt the new electric motors to the old machines, which continued to be useful and productive.

Planned Research

This article has presented a mere beginning of the research, both ongoing and planned, at the Page Belting Company. Ongoing, for example, is the inventorying of company documents, photos, and other material that help to define the firm's technical and cultural history. Planned is a major oral history project in which descendants of both working- and management-class employees will be interviewed. Preliminary research indicates that at least one ethnic group emigrated from Europe for the sole purpose of employment at the firm. Other aspects of the oral history may include attitudes and practices that contributed to the company's longevity.

The architecture of the 1890s' factory buildings, considered "state of the art" at the time of their construction, will be thoroughly documented. The very early years, when the company tanned its own hides, will be investigated to learn more of the process that brought tanning from a summertime outdoor activity to the indoor factory. Also on the research schedule are the company's diversification into harness manufacture, production of leather hydraulic packings and diaphragms, and textile mill and loom specialties; and sales of steam and plumbing supplies and sawmill machinery. If possible, Page's significant contributions to belting technology and its position within the greater industry will be identified. Industrial archeologists are fortunate to have this viable manufacturer to serve as an important laboratory for cultural and technological research.

Notes

1. Howard J. Cromwell, *A Treatise on Belts and Pulleys* (New York: John Wiley & Sons, 1885, 1903), p. v.
2. William Worthington, Jr., "Belting Archeology," *IA* 15,1 (1989):63–64, quote on 63.
3. Dr. O. Conrad Trulson, president of Page Belting Company, estimated in 1992 that 15 firms in the United States could manufacture leather power transmission belting, while Page Belting Company is one of only two that operates a curry shop capable of processing leather for power belting. Manufacturers who do not operate a curry shop must purchase belting leathers from the two that do.
4. Standards for leather power transmission belting by United States Steel Corporation (October 1921) and the United States Bureau of Standards (October 1923) were published by George B. Haven and George W. Swett in *Treatise on Leather Belting* (New York: American Leather Belting Association, 1931), pp. 177–190.
5. Theodore Z. Penn, "The Development of the Leather Belt Main Drive," *IA* 7, 1 (1981):1–14.
6. Oliver Evans, *The Young Mill-Wright & Miller's Guide* (Wallingford, Pa.: Oliver Evans Press, 1990, reprinted from 1795 first edition).
7. Some of Thomas Blanchard's machines are illustrated by Carolyn C. Cooper, "'A Whole Battalion of Stockers': Thomas Blanchard's Production Line and Hand Labor at Springfield Armory," *IA* 14,1 (1988):36–56.
8. Anthony F. C. Wallace, *Rockdale: The Growth of an American Village in the Early Industrial Revolution* (New York: W. W. Norton, 1980), p. 131.
9. Charles T. Page, *History of the Page Belting Company 1871–1927 Concord, New Hampshire* (Penacook, N.H.: W. B. Ranney, 1927), pp. 3–7.
10. Ibid., pp. 7–9.
11. Ibid., pp. 15–16.
12. Robert W. Drake, *Fifty Reports on Mechanical Power Transmission from Motor Drive to Industry* (New York: American Leather Belting Association, 1934), pp. 113–114.
13. Ibid.
14. Cromwell (n. 1 above), pp. iv–vii.
15. Page (n. 9 above), and *Catalogue of Leather and Rubber Belting and Mechanical Rubber Goods. Straps of all Kinds, Lace Leather, and Mill Supplies. Practical Rules for the Purchase and Use of Belting. Also, Kinds and Grades of Belting To Use For Different Kinds of Work* (Concord, N.H.: Page Belting Company, 1894), p. 6.
16. David R. Starbuck, "The Timber Crib Dam at Sewall's Falls," *IA* 16, 2 (1990):41–57.
17. A number of company documents and a newspaper account (*Concord Monitor*, February 9, 1968, p. 7) proudly state that the three motors purchased from General Electric Company operated for more than 50 years. General Electric replaced one of the original motors (c1970) and now exhibits it at its museum in Schenectady, New York.
18. Page Belting Company documents.
19. *Catalogue* (n. 15 above), pp. 61–79.
20. Ibid., pp. 36–43.
21. Haven and Swett (n. 4 above) fully describe the physical properties of belting leather, pp. 12–20.
22. The Page currying process, little changed in a hundred years, is perhaps more complicated today than it was in the 19th century because of vastly changed market conditions. In the past, at the height of the utilization of leather power transmission belting, many tanneries produced bends specifically for that application. In a market with many suppliers and many belting makers, the quality of belting leather was high and its price competitive. In recent years, the number of tanneries operating in the United States has dropped dramatically. Needless to say, the demand for belting leather is very low compared to the demand for other grades, so that belting bends are no longer produced. To obtain leather suitable for power belting today, Page must purchase outsole leather bends (meant to be applied to the soles of shoes and boots) at relatively high prices for its curry shop. Sole leather bends, while originating from the area of the steer's hide which produces the best belting, are highly impregnated with such fillers as sugar and Epsom salts (up to 20 percent by weight) to render them stiff and hard. A necessary operation in the modern curry shop, therefore, is washing the salts, sugars, and other hardeners out of the sole bends.
23. Typical of such handbooks is Erik Oberg and F. D. Jones, *Machinery's Handbook* (New York: Industrial Press, 1964). Haven and Swett (n. 4 above) also provide good applications information.
24. A copy of this specification was shown to the author by Al Arsanault, a former employee.
25. Haven and Swett (n. 4 above), pp. 182–190.

National Styles in Engineering: The Case of the 19th-Century Suspension Bridge

Emory L. Kemp

Using a case study of the early modern suspension bridge, 1801–70, the issue of national styles in engineering is explored in the context of social and economic history. Different styles emerged in Britain, France, and the United States as a result of the organization of the profession of civil engineering, including the education of engineers, which in turn expresses cultural as well as technical values in each country. The British bridges are notable for their solidity, permanence, and monumental appearance. In contrast, French suspension bridges symbolized the French achievement in the application of theory to practice. Their concern for clarity of expression in music and literature was also manifest in bridge engineering. In their zeal to complete works quickly and with maximum economy in a nation where capital was in short supply and labor was expensive compared to European practice, American civil engineers created works that often had an unfinished appearance in contrast to the elegance and monumentality of British and French bridges. Nevertheless, American bridges showed an ingenious application of construction principles to erect truly remarkable structures, using wire cables together with traditional materials such as stone and timber. In all cases, the suspension bridge proved to be a most attractive structural form for the erection of long-span bridges in an era of rapid industrialization and the need for improved transportation networks.

The Context for Suspension Bridge Styles

Consideration of "style" in the building arts is usually in terms of architecture; it is also relevant to the case of suspension bridges since 19th-century bridge engineers were influenced by successive revivals of current architectural styles. Thus one sees Classical, Gothic, and even Egyptian revival finding expression in what was considered by architecture critics and many others to be utilitarian engineering structures.

A study of the development of suspension bridge technology reveals more subtle and important expressions of national characteristics based on rather different approaches to engineering analysis, design, and construction as applied to bridge building. The organization and education of engineers also played a role.

In addition, styles result from the economic, social, and cultural conditions of the time and in the various countries. In the case of suspension bridges, the necessity for long-span bridges is not only a function of developing transportation systems but also of the topography of the country. It is therefore not surprising that American engineers saw in the suspension bridge the means of erecting long spans across wide and deep natural watercourses on a continent-wide basis. Although wire cables proved to be superior for long-span bridges compared to the earlier chains composed of links or eyebars, the adoption of wire cables in France and America during the first half of the 19th century was on the basis of the availability and reasonable cost of wire compared to bars. Neither country had the iron industry to produce large wrought-iron eyebars to assemble a suspension chain and, therefore, they used wire, which could be easily and economically produced. Britain was virtually the only country in which large wrought-iron components could be provided economically and in quantity. Compared to other structural forms used in bridge engineering, the suspension principle was much cheaper for medium- and long-span bridges than any other.

Architecture has been called the most social of the fine arts because it depends on clients, whether public or private, who supply the resources for the building of structures considered to be of architectural merit. Much more than the solitary artist, the architect is limited not only by the funds available, but also by the requirements of the client, including his aesthetic sensibilities or lack of them. The architect is also conscious of the aesthetic judgment of his peers. These conditions existed, to a large extent, in public works designed by engineers that played such a prominent role in the building arts in the Victorian era. The works were conceived, designed, and constructed by engineers in charge of armies of workers, since the projects were labor-intensive and lacked the sophisticated equipment one associates with modern large-scale building. In terms of architecture alone, one can argue that the most significant structures of the Victorian era were engineering works needed for the new industrial age.

To many, the most significant building of the time was London's Crystal Palace of 1851. The use of glass and iron for its principal components, rather than traditional materials, confounded architectural critics and led them to conclude that it was "non-architecture." The building not only represented Britain's role as the world's first industrial society but proclaimed the use of iron in the building arts. The iron frame symbolized Britain's leadership in producing large cast- and wrought-iron components, not only for civil engineering works but also for mechanical engineering designs, especially steam engines. The Crystal Palace represented the high tide of Britain's industrial supremacy and more than half a century of the construction of engineering works on an unprecedented scale. France and America were also swept up in expanding industrialization, albeit on a different time scale and at a different rate.

Insights into national styles in engineering may be gained from one or two selected case studies. One could argue that the steam locomotive was the leading technology in the field of mechanical engineering and as such lends itself to such a case study. In the case of civil engineering, bridges provide an especially enlightening case study. And of all the bridge types used in the 19th century, it was the suspension that achieved the greatest transformation, going from a primitive span to a powerful new technology exceeding 1,000 feet clear span by mid-century. It was made possible by a new structural material, wrought iron, used in a most efficient manner—direct tension.

Engineering Traditions in Britain, France, and America

Perhaps the best way to explore the subject is to discuss briefly the engineering traditions in Britain, France, and America and see how these manifest themselves in the building of suspension bridges. Although France followed Britain in the process of industrialization, it was the French who laid the foundations of modern civil engineering beginning in the 17th century.

The profession of civil engineering, as distinct from the craft of building, arose in France during the reign of the Sun King, Louis XIV (1638–1715). Under his able minister of finance, Jean Baptiste Colbert, and leading engineers such as Pierre-Paul de Riquet, an internal improvements program was undertaken which, like the U.S. interstate highway system in our day, served perceived military needs and at the same time provided the arteries of commerce. The program was conceived in the "Grand Manner" so typical of Louis XIV in both scope and elegance. The Languedoc Canal built under Riquet is an outstanding public works project of the time. It was completed in 1681 and comprised 100 locks in a length of 148 miles. The 500-foot-long tunnel at Malpor and the summit-level reservoir at St. Féréole attracted international attention. On the military side, formidable fortifications were constructed by S. Vauban, the leading military engineering specialist.

To meet the need for engineers for these great public works, a Corps des Ingénieurs des Ponts et Chaussées was established in 1716 independent from the Corps du Génie of the French Army, founded in 1676. It was reorganized by J. R. Perronet, a leading bridge engineer. This school provided the formal technical training necessary for entering the Corps. After the French Revolution, the École Polytechnique was founded in 1794 to provide a centralized academic institute for the education of engineers based solidly on mathematics and mechanics. Thus, by the end of the 18th century, engineering in France had been thoroughly professionalized.

Following Perronet (1708–94), a distinguished group of engineers including E. M. Gauthey (1732–1806), C. Navier (1785–1836), and L. J. Vicat (1786–1861), all associated not only with research and teaching but also with the practice of bridge building, added to the luster of the École des Ponts et Chaussées.[1]

It would be difficult to imagine a greater contrast in engineering than France and Britain in the 18th century. Lacking a strong central government involvement in the industrialization process, British craftsmen, inventors, and builders became engineers through an apprentice system. In the 17th century, the Royal Society, with its Baconian emphasis on experimentation and the application of scientific knowledge to practical ends for the benefit of mankind, made an indelible mark on engineering which persists to a large extent in the English-speaking world to this day, in contrast to the European approach to engineering with its emphasis on basic mechanics and mathematics.

In the absence of government control and patronage, engineering organizations were late to form in Britain and in the beginning consisted of informal groups of engineers gathered to discuss their work and the latest scientific literature. The first of these appears to have been the Smeatonian Society established by John Smeaton (1724–92). The Society of Arts, founded in 1754, offered prizes to stimulate invention but could hardly be compared to the French government agencies. The Institution of Civil Engineers was not founded until 1818, and the first formal education at colleges and universities did not appear until the 1820s, if one excludes lectures in natural philosophy given at the University of Edinburgh beginning in the latter half of the 18th century. The British took fierce pride in their empirical approach to engineering and the apprentice system of education. Thomas Telford (1757–1824), perhaps the most famous British civil engineer, began as a stonemason. He flourished in what can only be described as the heroic age of civil engineering, which lasted until the Great Exhibition of 1851, and in selected cases even longer. Civil engineers who became legendary in Britain during the Victorian era included Isambard Kingdom Brunel (1806–59), George (1781–1848) and Robert (1803–59) Stephenson, William Jessop (1745–1814), and John Rennie (1761–1821), all noted bridge engineers. There were of course a legion of others involved in a variety of engineering projects. Their engineering knowledge was gained not only from experience but in published articles in the civil engineering literature. An important source of information was encyclopedia essays by such noted academicians as John Robison, Thomas Young, and Thomas Tregold, to name just a few associated with bridge building.[2]

These engineers without formal training were responsible for some of the most remarkable structures of the age. Their services were in demand not only in the United Kingdom but overseas as well. Reinforced by their successes, they remained true to their tradition. Writing about Telford's 580-foot-span Menai Suspension Bridge, his associate W. A. Provis said: "It is true that their ordinates might have been determined by calculations but with a practical man an experiment is always more simple and satisfactory than theoretical deductions."[3]

In many respects American engineers followed British precedent and established their own engineering tradition through experience and self-education. New ideas were gleaned from international literature, from visits to Britain and the Continent, and from employing foreign engineers. This represented the transfer of a British tradition to American soil. In numerous cases it was British money that helped finance the building of the nation's transportation system, including bridges.

There was, however, a group of engineers trained in the French tradition available to the American civil engineering fraternity: the graduates of the military academy at West Point. Established in 1802, the academy was set up in the French manner and featured military engineering with a strong emphasis on civil works. In addition, the U.S. Army Corps of Engineers was established to construct and operate a system of waterways, including canals and river navigations, on a federal basis. The Corps of Engineers employed many of the West Point engineering officers in large-scale navigation works for military objectives as well as the development of waterborne commerce. In an unprecedented move, the federal government seconded engineering officers to civilian projects. On both the Baltimore & Ohio Railroad, started in Baltimore in 1828 and reaching Wheeling, West Virginia, in 1852, and the National Road, stretching from Cumberland, Maryland, to Wheeling, West Point officers were employed as the only trained engineers. Col. Stephen Harriman Long (1784–1864) was a member of the U.S. Army Topographical Engineers but became a bridge engineer as a result of his work on the Baltimore & Ohio. Benjamin Latrobe credits him with being the foremost civil engineer of the antebellum period. He is symbolic of a number of military engineers involved in large public works.

Even though there was a continuous flow of technical information among Britain, France, and America, national styles are readily apparent in the works of engineers in these three countries in the first half of the 19th century.

The Development of the Suspension Bridge

The suspension bridge is apparently a classic example of the independent origin of an invention, developed in the high alpine regions of the Himalayas and the Andes more than 2,000 years ago. Information on these vernacular bridges reached Europe from a variety of sources over a period of a century or more. In a different development, the mathematical solution of the funicular polygon and the catenary curve had appeared by the end of the 17th century. This theoretical information was applied by French engineers, in particular, during the 18th century as a means of analyzing the forces in an arch, which was recognized as the inverse of the suspended chain. In addition, practical information on the strength of building materials was available to engineers in the technical literature.

These separate streams of information found a confluence in the work of Judge James Finley of Uniontown, in what was still the wilderness of western Pennsylvania. He designed and built what must be considered the first modern suspension bridge in 1801. This diminutive span of only 70 feet nevertheless had a level deck for wheeled vehicles, iron chains for the suspension structure, supporting trusses used to stiffen the deck, and timber towers and masonry anchorages. Finley patented this modern structural form in 1808; the patent drawing is shown in figure 1. It is clearly a

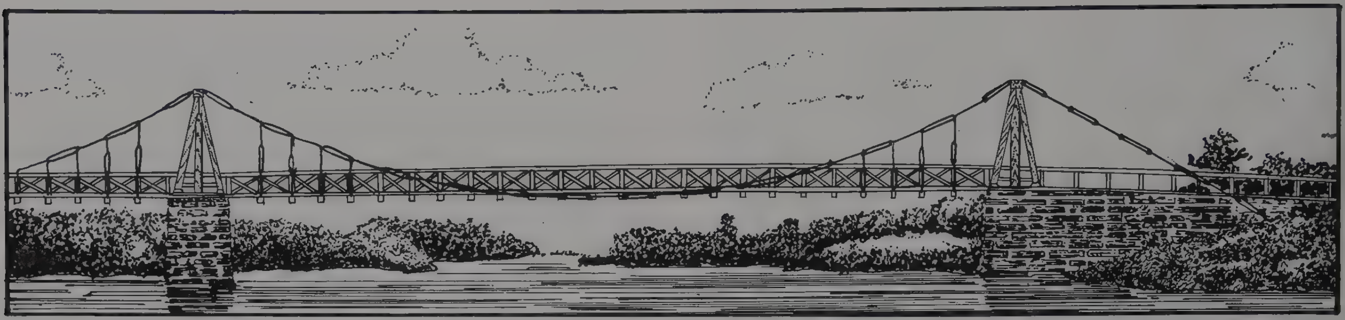


Figure 1. *Finley's patented chain-link bridge*. Smithsonian Institution.

utilitarian design, although possessing a certain elegance of form, with simple and carefully worked out details which could be executed by a blacksmith.

At a more basic level, Finley epitomized the Baconian ideal of the application of scientific principles for the betterment of mankind and the central role of the experimental approach to science. Through the use of experiments on loaded strings with various sag-to-span ratios, he was able to determine not only the geometry of the suspension chains, but also the forces in the chains from mid-span to the towers. It was truly a remarkable achievement. In 1810 Finley published an article in *Portfolio Magazine* describing in detail his new suspension bridge. He gave details of the experimental program which led him to determine the geometry and strength of the chain. He ended his description by saying: "I know the young mathematician with mind half matured would smile at my mode of testing the relative force and the effect of several ties and bracings on any piece of framing, but the well informed will not so lightly treat any information obtained or supposed to be obtained by actual experiment. If the process is before him, he will carefully ponder all the parts and discover where the defect before he rejects the conclusions drawn therefrom."[4]

This was, in effect, Finley's answer to the French school and its mathematical approach to engineering. From 1801 until his death in 1828, more than 20 Finley chain bridges were erected in America. The Lehigh Gap Bridge of 1826 served for a century and is an outstanding example of a Finley patented bridge (figures 2 and 3).

The British Contribution

The next stage of development was the use of more efficient eyebar chain or wire cables in place of link chains. Finley's work was known in Britain through his article in *Portfolio* and by reference in Thomas Pope's book on bridge architecture.[5] Finley's idea was accepted with alacrity by the British, who improved the technology by using rods and eyebars for the main chains and suspenders. Sir Samuel Brown was the pioneer in this development and secured patents for various chains composed of rods or bars. Brown was a retired Royal Navy captain who set up an ironworks in the Isle of Dogs on the Thames near London. He introduced iron instead of hemp rope for standing rigging in naval ships and clearly found a new market for his products in suspension bridges.

A detail of one of Brown's patent designs for the chain bridge of 1820 connecting Scotland and England is shown in figure 4. The general view of the bridge is shown in figure 5. Like Finley, Brown produced a simple but elegant solution for the bridge, without architectural embellishment or the adaptation of a particular architectural style in the towers. His structure exemplifies the emphasis British engineers placed on permanence and solidity for their great public works. In fact, the civil engineering component of British railways was called "the permanent way." With this idea in mind, Brown, Telford, William T. Clark, Brunel, and others eschewed the use of wire for suspension bridges. Brown stated what was to become the British position on this matter:

> A bridge of wires, being the most complicated of any, is the most objectionable. Where they are intended merely for the accommodation of foot passengers they may be easily contrived and constructed, but one composed of such slender and ductile material, of sufficient strength to support the weight of loaded carriages, must consist of such a multiplicity of parts that an united effort by their proper adjustment is not to be expected. The lack of durability is of itself an insufferable objection to wire bridges, as well as all others constructed of such slender filaments. The immense surface exposed to the action of the atmosphere would infallibly cause a rapid decay, and the common preventatives of corrosion could not be made generally beneficial because it is impossible to apply any composition to the interstices and crossings of the

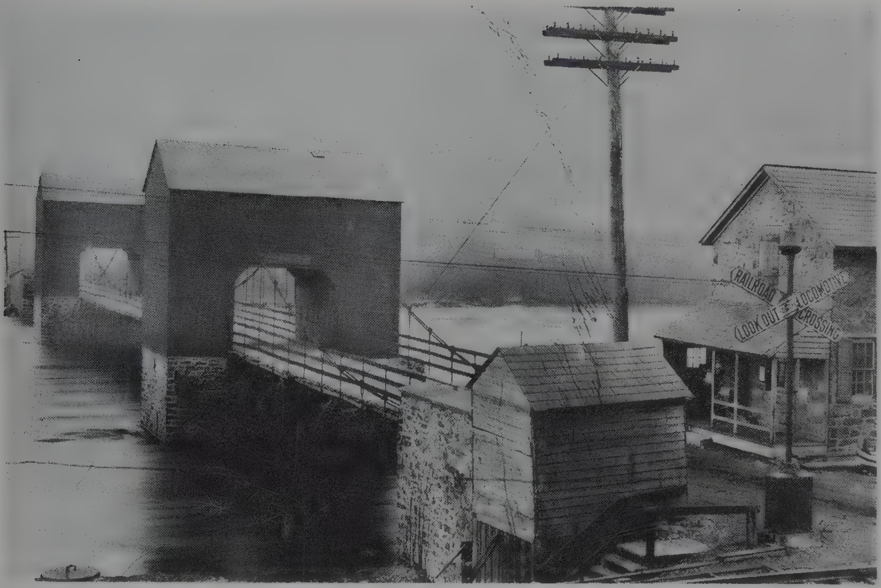


Figure 2. *General view of Finley-type chain bridge at Lehigh Gap, completed in 1826*. Palmerton, Pennsylvania, Camera Club.

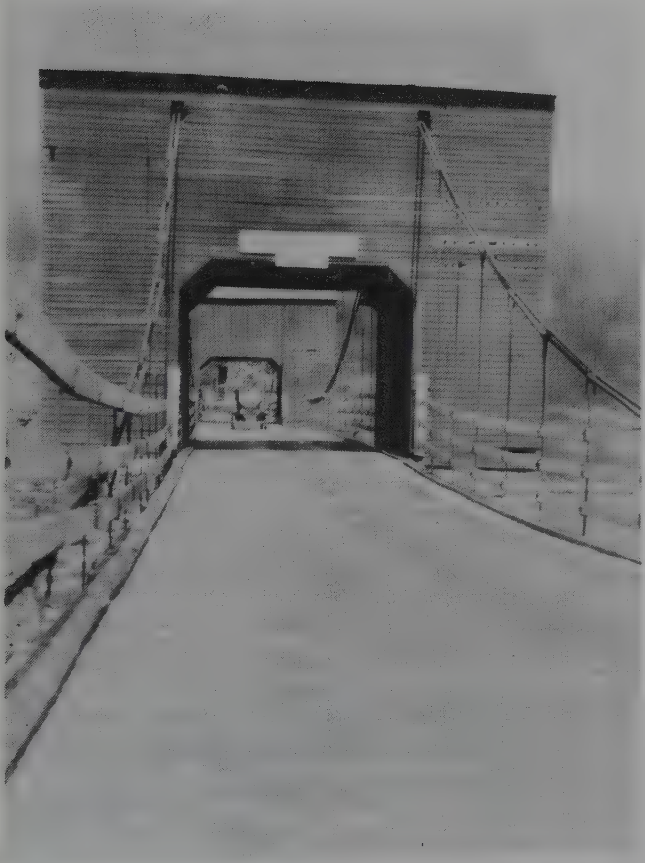


Figure 3. *Lehigh Gap Bridge showing the suspension chains, towers, and deck*. Smithsonian Institution.

> wires or seams of the filaments where they are most liable to be effected; and as the defects cannot there be observed, the bridge might be in a state of dangerous insecurity while it indicated no appearance of decay.[6]

Thomas Telford was involved in all manner of great public works, ranging from roads and bridges to canals and harbor works. His career was largely restricted to his native Britain, but it should be noted that he was the chief engineer of the Gothenburg Canal, for which he was knighted by the king of Sweden.

At the beginning of the 19th century, he was seeking a chance to build a long-span bridge; he proposed a cast-iron arch bridge over the Thames, but it was not built. His chance came with a high-level bridge across the Menai Straits in Wales. To meet clearance requirements established by the Admiralty, the bridge had to have a clear span of nearly 600 feet and a height above high water sufficient to clear the masts of sailing warships. Telford turned to the suspension principle and produced the greatest bridge of his day, which featured massive stonework and heavy eyebar chains as shown in figure 6. He relied on experimental results by utilizing, on a very large scale, the Finley approach of loading a model. Not only did he rely on such results, he ensured that each eyebar in the chain was tested and proof marked. Davies Gilbert, president of the Royal Society, was involved in the bridge in an advisory capacity and convinced Telford and the bridge committee through his analysis to raise the height of the towers to reduce the stresses in the main cables. Earlier, Telford had proposed that each of the chains be anchored sequentially in the stone viaduct approaches to both of the towers. With the modifications made by Gilbert, this was unnecessary, and the approaches could have been supported directly from the bridge's backstays. The Menai Bridge remained the greatest British suspension bridge for more than a century.

Telford, more than any other engineer, was responsible for establishing the British civil engineering profession firmly based on craft tradition. He served as one of the first presidents of the Institution of Civil Engineers. Once, when asked to employ a university graduate, he was said to have offered him a position *despite* his university education and his background in mathematics.

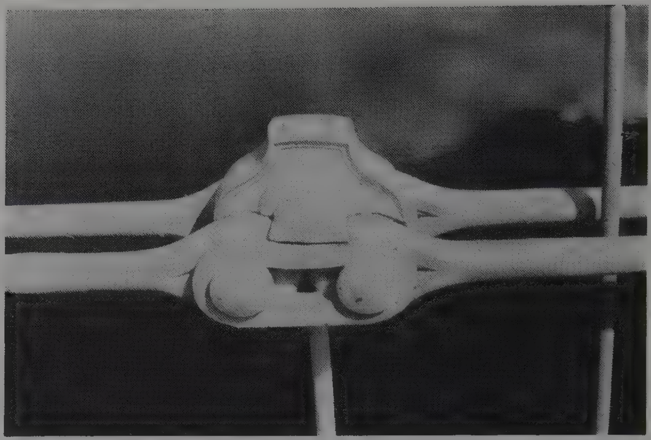


Figure 4. *Detail of Union Bridge chain-suspender joint.* Photo by the author.

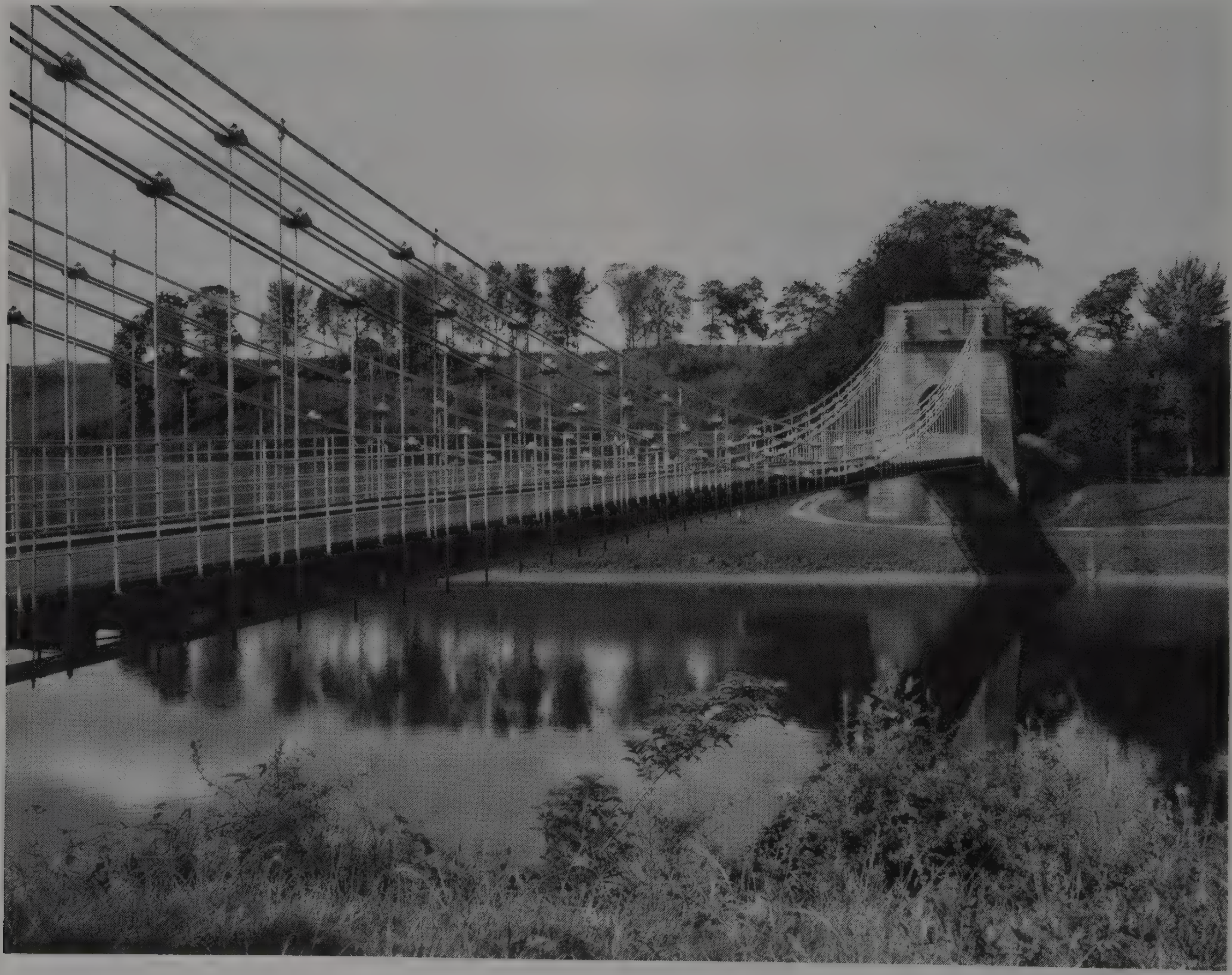


Figure 5. *Brown's Union Bridge, opened 1820.* Photo by the author.

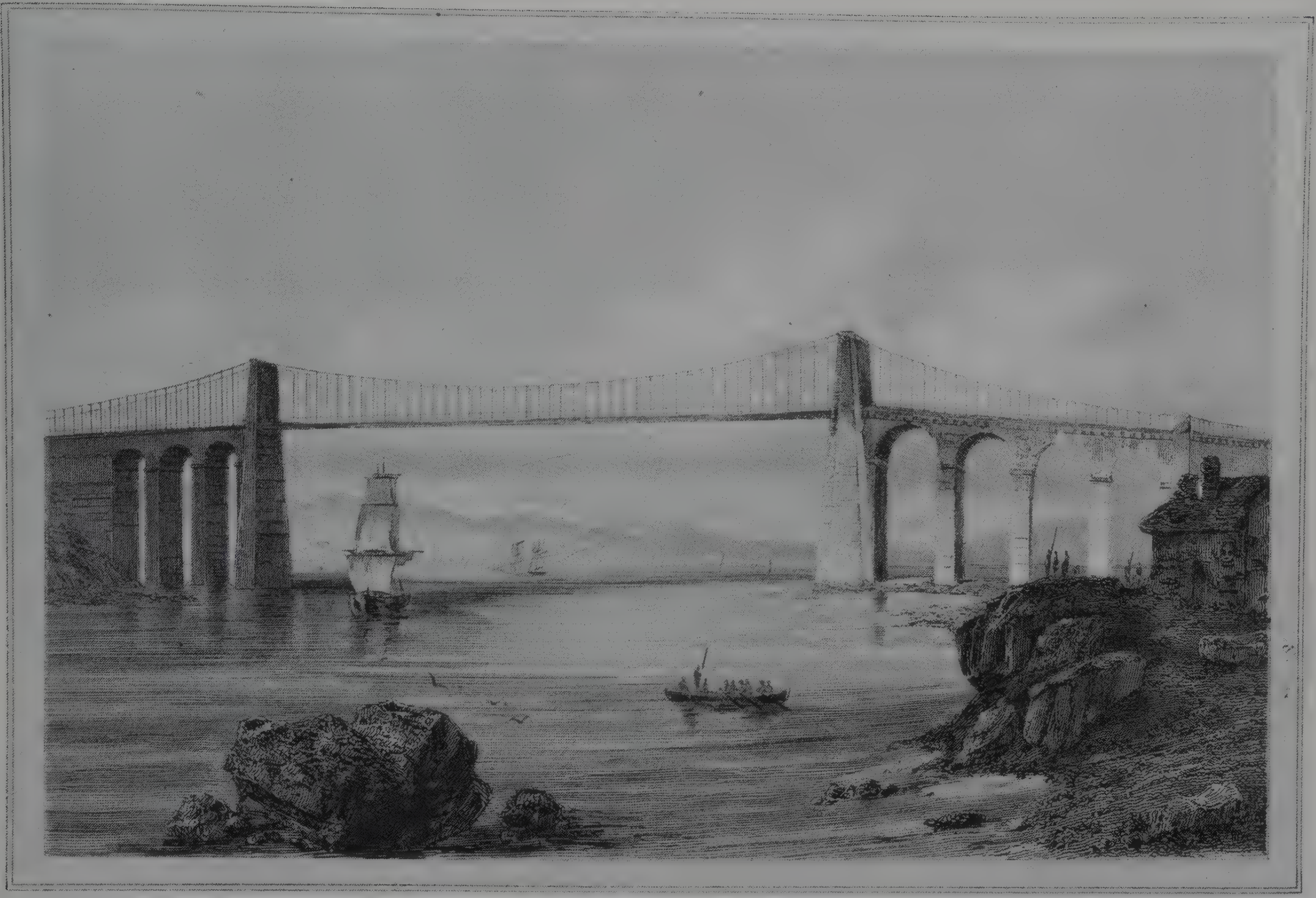


Figure 6. *A c1825 etching of Telford's Menai Straits Bridge, opened 1826.* Author's collection.

While recovering from injuries sustained in the construction of the Thames Tunnel, I. K. Brunel became involved in a proposal to build a bridge over the Avon Gorge in the Bristol suburb of Clifton. A number of designs were submitted in a competition, including those by Brown and Telford, as well as Brunel. They ranged all the way from Telford's rather timid design using Gothic towers rising from the gorge to bridges spanning more than 700 feet across the gorge. The most interesting with regard to style is Brunel's use of Egyptian revival motifs. In the 1830s it was felt that because of the durability and solidity of Egyptian buildings, Egyptian revival details might be most appropriate for great public engineering works, leaving Classical styles for public buildings and banks, with Gothic revival to be used for churches and educational institutions. Brunel was very enthusiastic and somewhat carried away in his design, using an Egyptian sarcophagus for each of his anchorages, with Egyptian architectural details on his towers as shown in figures 7 and 8. Building commenced in 1836 but was not completed until 1864 (Brunel died in 1859). Although his exuberant architectural details were not completely incorporated in the structure, the Egyptian motif is subtly expressed in the towers.

Enter the French Engineers

The work of Brown and Telford came to the attention of engineers at the École des Ponts et Chaussées, and its director sent none other than Claude Navier to investigate the new British technology. In 1823 Navier published his report covering all aspects of the subject, including applications to structures such as canal aqueducts. His landmark *Mémoire sur les ponts suspendus* introduced the British eyebar approach to suspension bridge building in France. But the French contribution rested on the wire cable.

The first (small) wire cable suspension bridges were built

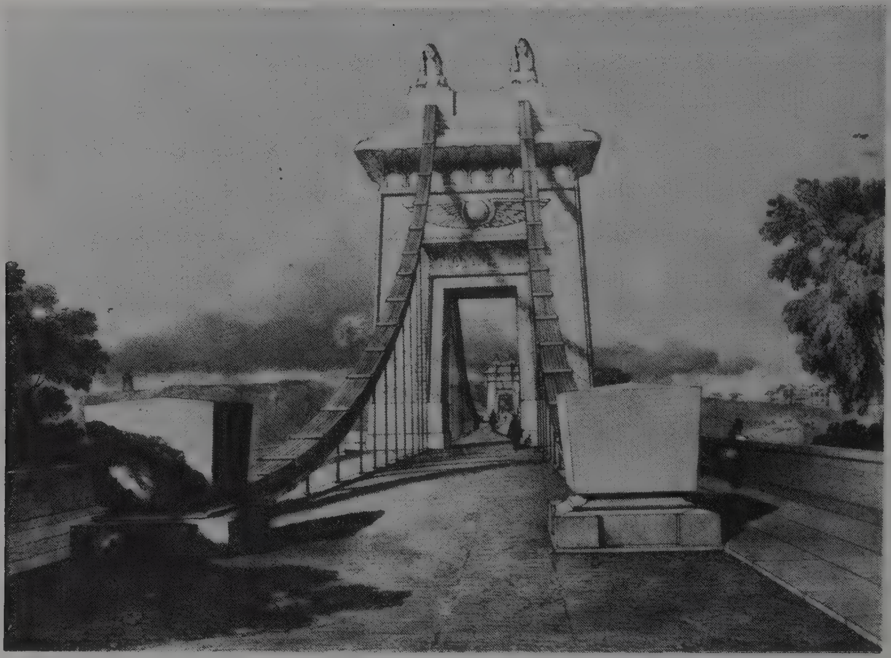


Figure 7. *Brunel's Egyptian-style design for the Clifton Bridge.* Early drawing by Brunel.

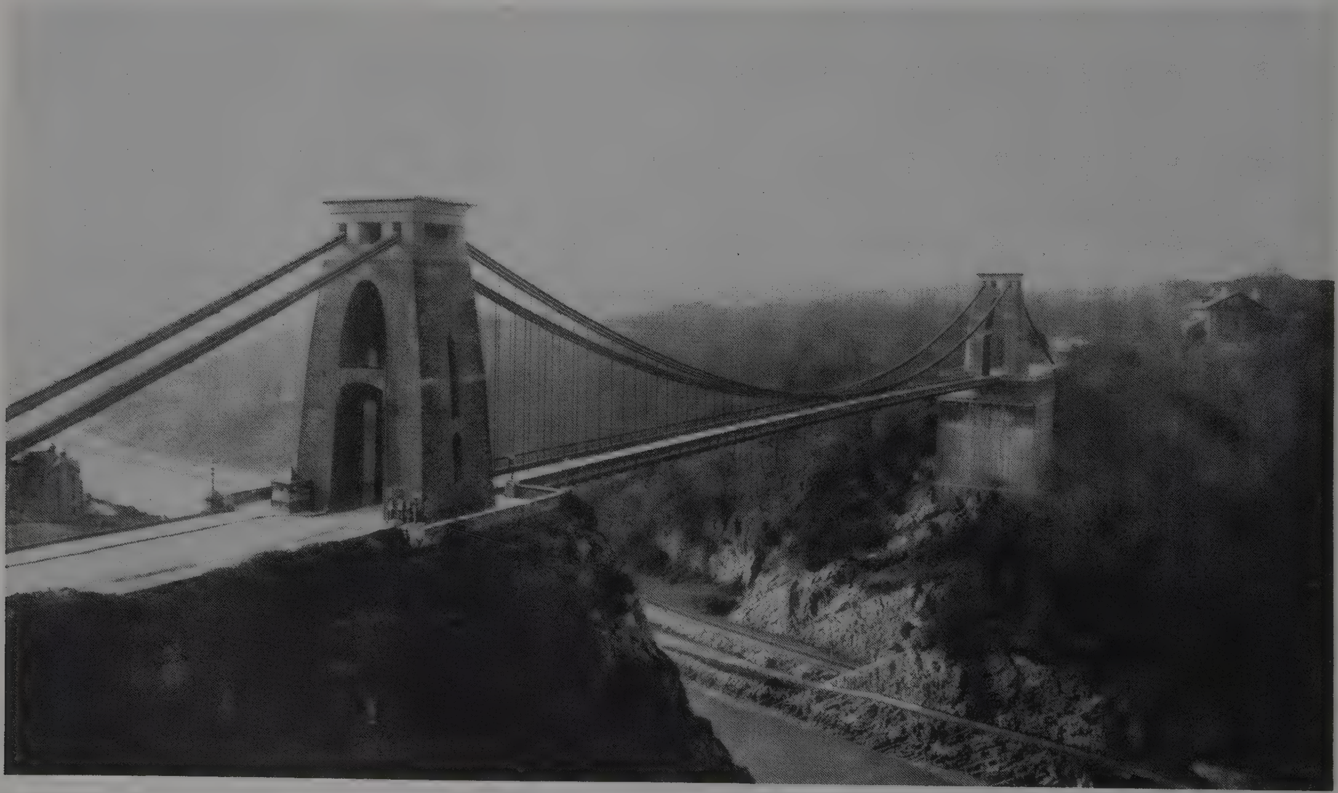


Figure 8. *A c1932 photo of the Clifton Suspension Bridge, completed in 1864.* *The Centralian,* Imperial College, London.

in 1816, one in Philadelphia and another at Galashiels in the lowlands of Scotland, when industrialists needed to provide a pedestrian bridge to connect factories separated by a river. Enter Marc Seguin (a nephew of J. Montgolfier of hot-air balloon fame), the eldest brother in a silk business family in Annonay, Lyon. Seguin also built a *passerelle* (foot bridge) for his employees based on his knowledge of Spanish wire bridges. With confidence gained in this venture, in 1825 he erected the first suspension bridge across the Rhone, at Tournon, and he and his brothers founded a wire suspension bridge-building firm. By 1870 the French had erected literally hundreds of new suspension bridges on a concession basis, with the designs and load tests approved by professional engineers in Paris. Despite Seguin's native genius (he later turned his attention to steam navigation on the Rhone and the improvement of railway locomotives), he was not a member of the Corps des Ponts et Chaussées. So the director of the Ponts et Chaussées sent Vicat, noted for his thorough research work as well as his practical engineering, to investigate the new wire cable bridges produced by the Seguin brothers.

Vicat's reports were models of thoroughness and of the clarity of thought and expression so highly prized by the French.[7] He discussed wire cables, anchorages, and the stability of towers and the design of deck and stiffening trusses, all shown in figure 9. As a result of his investigation, Vicat became an ardent advocate of the suspension bridge and of the superiority of the wire cable compared to the eyebar favored by the British. His ideas are faithfully incorporated in the Pont Mallemort over the Durance River (see figure 10). His support for wire cables was twofold. First,

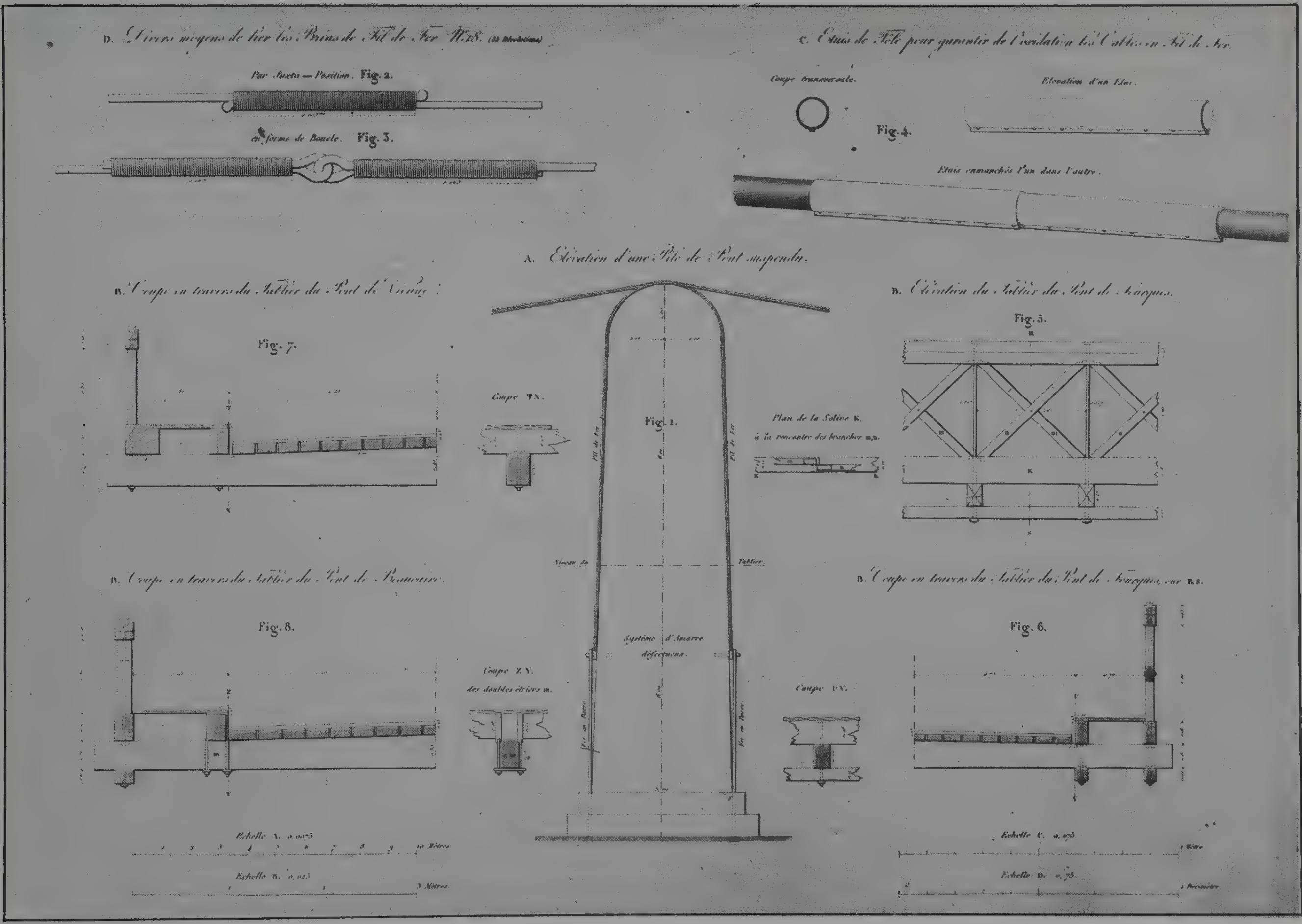

D. Divers moyens de lier les Brins de Fil de Fer No. 18.
Par Juxta — Position. Fig. 2.
en forme de Boucle. Fig. 3.
C. Etuis de Tôle pour garantir de l'oxidation les Cables en Fil de Fer.
Coupe transversale.
Elevation d'un Etui.
Fig. 4.
Etuis emmanchés l'un dans l'autre.
A. Elévation d'une Pile de Pont suspendu.
B. Coupe en travers du Tablier du Pont de Vienne.
Fig. 7.
B. Elévation du Tablier du Pont de Fourques.
Fig. 5.
Coupe TX.
Fig. 1.
Plan de la Soliva K.
Tablier.
B. Coupe en travers du Tablier du Pont de Beaucaire.
Fig. 8.
B. Coupe en travers du Tablier du Pont de Fourques
Fig. 6.
Système d'Amarre défectueux.
Coupe Z.Y.
des doubles étriers m.
Coupe UV.
Echelle A.
Echelle B.
Echelle C.
Echelle D.

Figure 9. *Vicat's suspension bridge details.* L. J. Vicat, "Ponts Suspendus en Fil de Fe sur la Rhone, Rapport," *Annales des Ponts et Chaussées* 1 (1831):93.

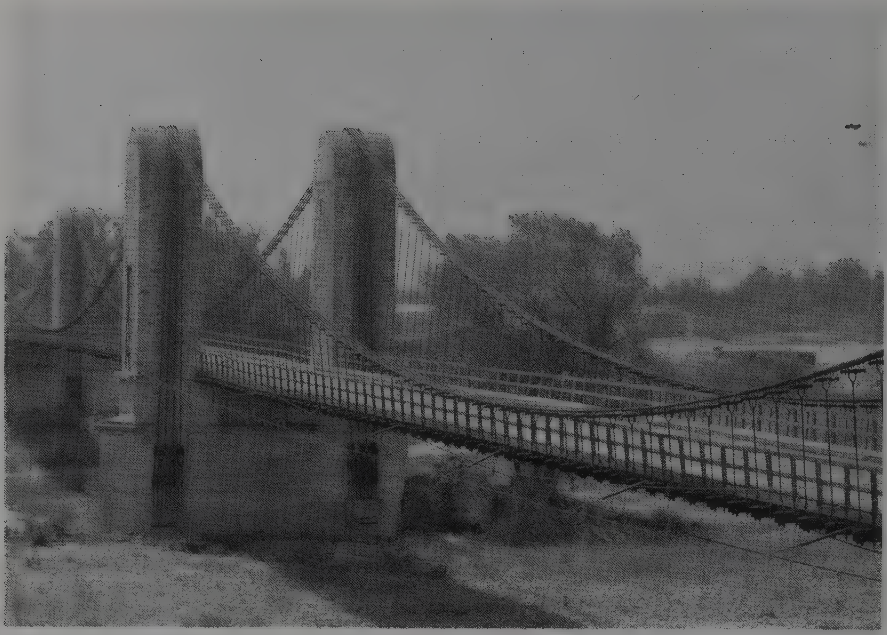


Figure 10. *Mallemort Suspension Bridge*. Photo by the author.

wire could be produced cheaply and in quantity in France, as opposed to the large eyebars favored by the British. Equally important from the engineering point of view was the act of drawing the wire through dies, for each wire was thus proof-tested as it was made. He was fearful that there would be defects in the wrought-iron eyebars that could not readily be detected.

One of Vicat's primary concerns was the durability and strength of the wire cables. With respect to durability, he conducted experiments coating individual wires with linseed oil, then applying red lead to the cables. (Observing that a number of his men suffered lead poisoning after working with the wire, he prescribed a diet that included consuming large quantities of milk in place of the wine ration!) Vicat was also concerned with how the cables could be laid out so that each wire would carry an equal load. The solution was wire spinning, which proved to be an essential technique in building large cables for very long-span bridges. Telford had to erect heavy lifting tackle to raise his chains for the 580-foot-span Menai Bridge. Engineers could not contemplate much longer spans unless the cables could be laid in place using a spider that spun a wire or two at a time. Thus the eyebar was limited to spans of 1,000 feet or less.

Following publication of Vicat's seminal papers, the French engineer Joseph Chaley began work on the Fribourg Bridge in Switzerland in 1832. It established the power and economy of wire suspension bridges and remained the longest clear-span bridge in Europe through the 19th century, with a span of 870 feet. It was a tour de force and represented clearly the happy marriage between theory and practice so favored by French engineers.

Earlier, Navier had introduced the idea of using an arc de triomphe for the tower of suspension bridges. He may have been familiar with the monumental design for Clark's Marlow Bridge over the Thames which was under construction during his visit to Britain. Chaley employed this architectural style on the Fribourg Bridge, as shown in figure 11. The style was used repeatedly throughout the country. The Valence Bridge of 1827 (figure 12) is an example of the use of the single tower and two half-spans. This design eliminated towers and backstays on the riverbank and was a decided advantage for short- or medium-span bridges in congested urban areas.

The French concern for clarity of expression and the theoretical basis behind a design is clearly manifest in the details employed on their bridges. For example, the roller detail in Jan Masaryk Bridge (figure 13) and the articulated cast-iron stanchions of the Pont St. George (figure 14), both built in Lyon at mid-century, reveal their designers' structural analysis assumptions. The form and function of each component are apparent in the finished work.

The American Experience

When introducing the use of wire cables for long-span suspension bridges, Charles Ellet was careful to credit the French as the originators of this new technology. He relegated his fellow countryman Finley and his chain-bridge invention to the same class as primitive bridge builders and their structures in the Andes and the Himalayas. Thus in many ways the Wheeling Bridge, completed in 1849, represents the final flowering of French design principles. It was a French bridge on American soil erected within 60 miles of three Finley chain bridges that were not mentioned in the literature.[8] It was Ellet's masterpiece.

Born in 1810 on a farm in Bucks County, Pennsylvania, Charles Ellet, Jr., eschewed an agrarian life and chose engineering as a career. His early experience was in land surveying, followed by service as an assistant engineer on the Chesapeake and Ohio Canal. Before his 20th birthday he made a decision to forego settling in Illinois with his family and to journey to Paris and enroll in the prestigious École des Ponts et Chaussées. It was during his brief sojourn in France that he first learned about the work of Navier, Seguin, Vicat, and Chaley, and he inspected a number of French wire suspension bridges, including the Fribourg, then under construction.

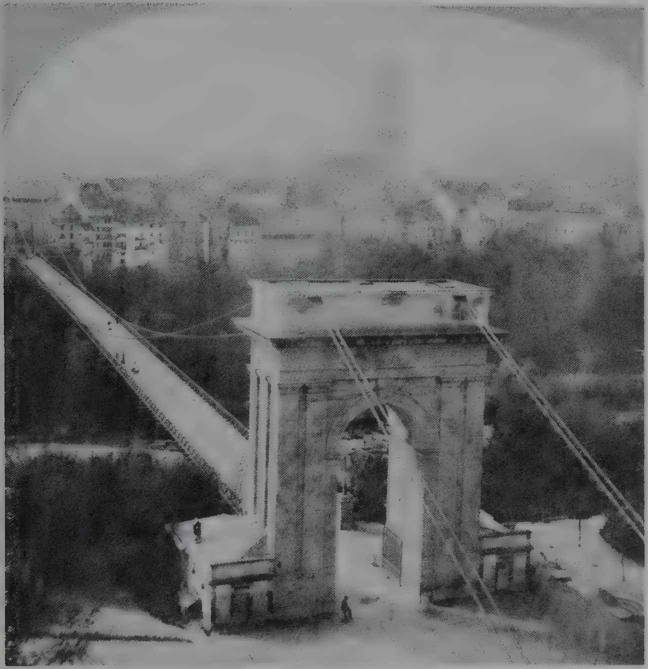


Figure 11. *Chaley's Fribourg Bridge, 1834.* Smithsonian Institution.

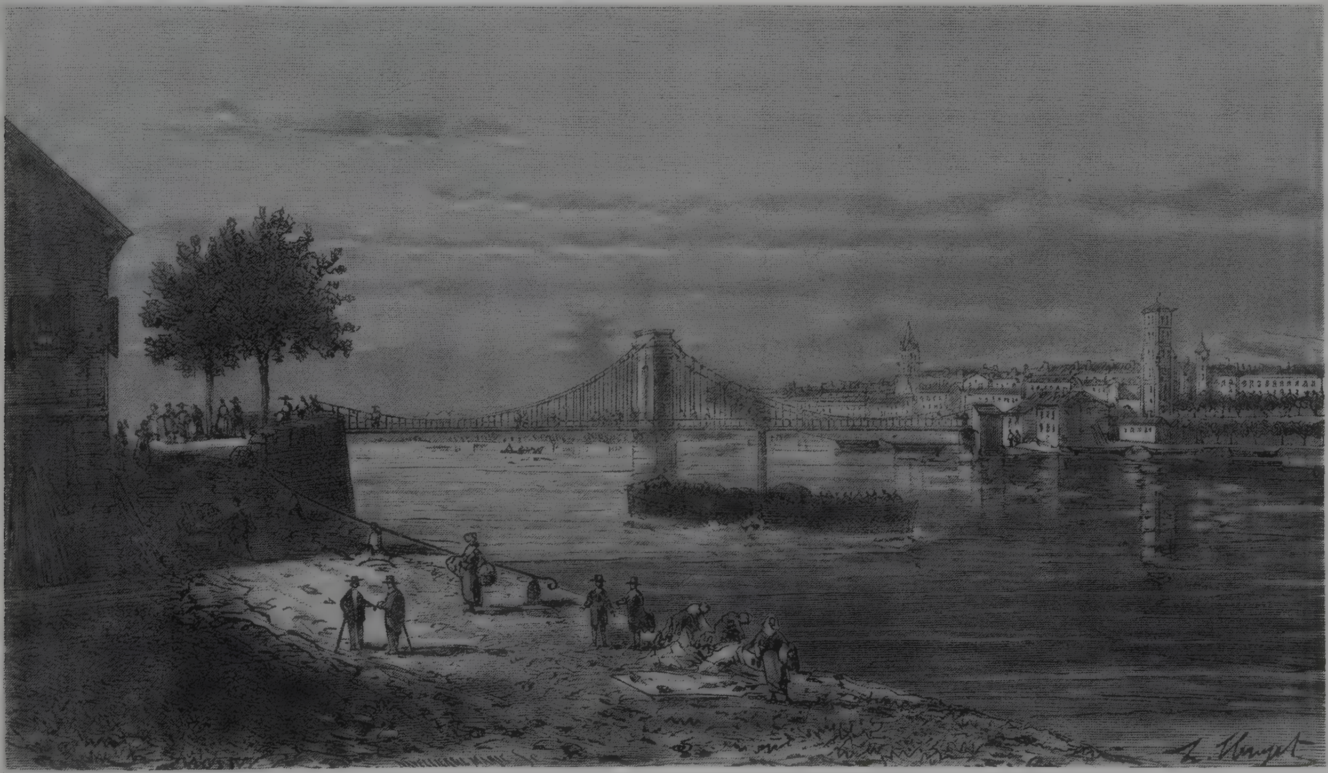


Figure 12. *An 1881 etching of the bridge at Valence.* Author's collection.

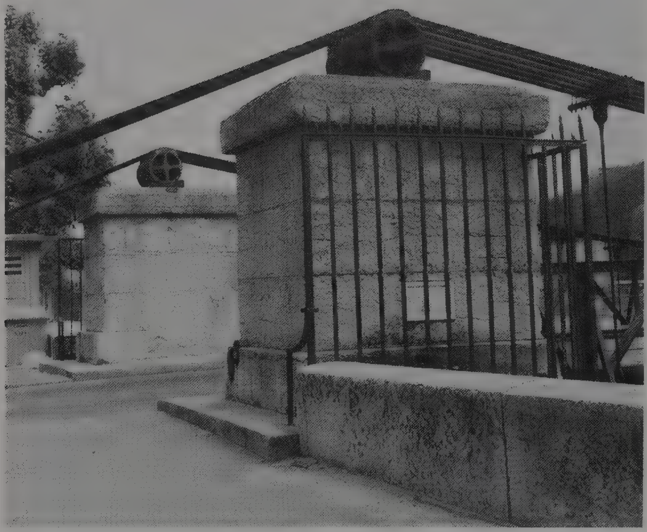


Figure 13. *Pont Masaryk, Lyon, 1830, showing a roller support.* Photo by the author.

For nearly a decade he promoted the French wire suspension bridge. One of his designs was for a 3,000-foot multi-span bridge across the Mississippi River at St. Louis, Although the bridge was not built, despite its low estimated cost of $625,000, the bridge report was Ellet's most comprehensive statement on the subject.[9] It clearly shows the influence of the French, particularly Navier. In 1838, when Lewis Wernwag's 340-foot-span timber bridge across the Schuylkill at Fairmount, Philadelphia (aptly named "Colossus") was destroyed by fire, Ellet had his first opportunity to build a wire suspension bridge, to replace Wernwag's great work. The French-style bridge was completed in 1842 and incorporated earlier French details in its garland wire cables, timber stiffening trusses, deck details, and tower designs (see figure 15).

In 1847 Ellet received the commission to design and build the Wheeling Suspension Bridge with a clear span of 1,008 feet, making it the longest bridge in the world at the time.[10] The garland system and deck details showed the French influence (see figure 16). Although French inspiration is apparent in Ellet's work, his designs had a decidedly American accent. In Ellet's case, the appeal of the French as opposed to the British approach to suspension bridge design was economy and efficiency, with little regard for many of the subtleties espoused by Vicat. In viewing French design details, one concludes that many of the refinements were meant for the appreciation of fellow engineers; this was not the case in America. The noted Scottish engineer David Stevenson reported on American bridge design:

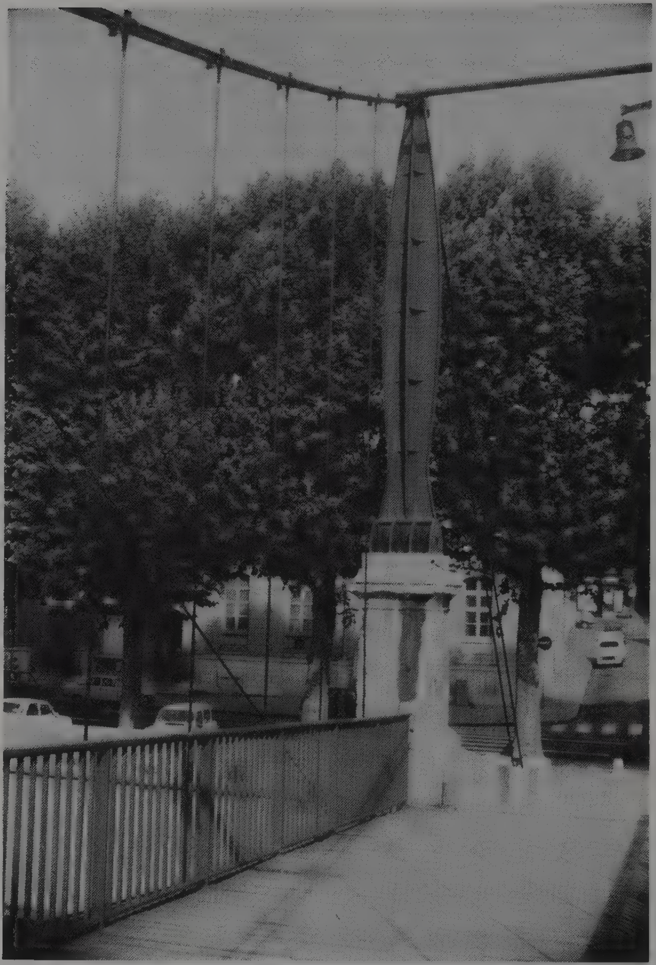


Figure 14. *The Seguin brothers' Pont St. George, Lyon, showing articulated cast-iron cable tower*. Photo by the author.

> The zeal with which Americans undertake and the rapidity with which they carry out every enterprise which has the enlargement of their trade for its object cannot fail to strike all who visit the United States as a characteristic of the nation. English and American engineers are guided by the same principles in designing their works but the different nature of the materials employed in their construction and the climate and circumstances of the two countries naturally produce a considerable dissimilarity in the practice of civil engineers in England and America. At first view, one is struck with a temporary and apparently unfinished state of American works and is very apt before inquiry into the subject to impute to want of ability what turns out on investigation to be a judicious and ingenious arrangement to suit the circumstances of a new country of what the climate is severe—a country where stone is scarce and wood is plentiful and where manual labor is very expensive. It is vain to look to American works for the finish which characterizes those of France or the stability for which those of Britain are famed.[11]

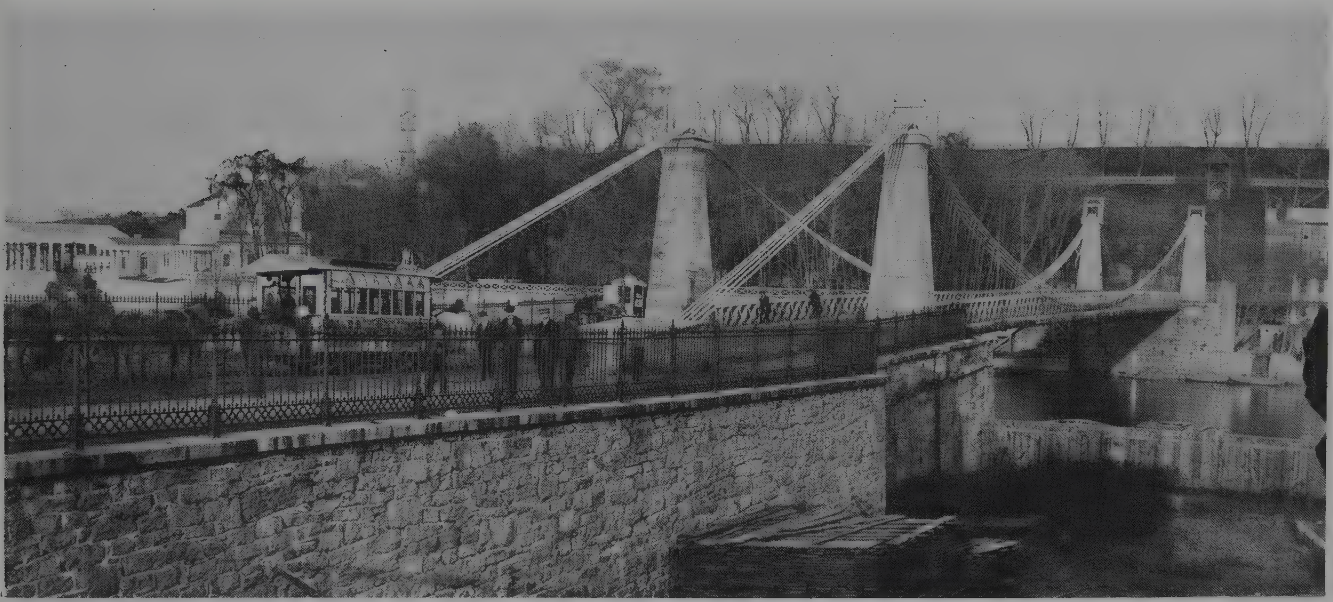


Figure 15. *Ellet's Fairmount Bridge, 1842*. Free Library of Philadelphia; Smithsonian Institution.

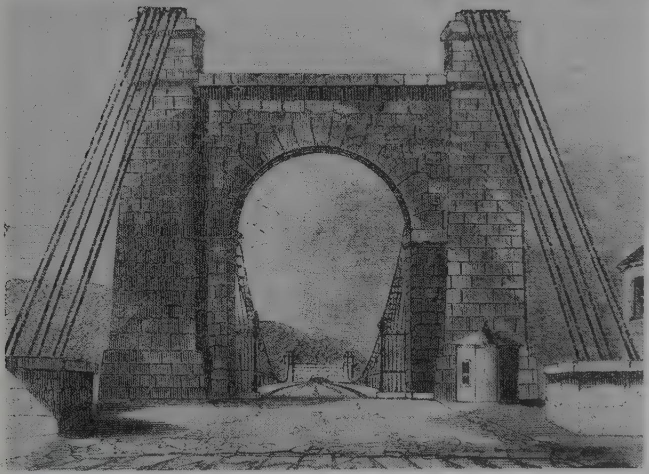


Figure 16. *Ellet's Wheeling Bridge showing the original garland cable system*. Author's collection.

The notable departure from French practice in Ellet's design at Wheeling was the massive stone towers in contrast to the use of an arc de triomphe tower. It was a utilitarian design, lacking the elegance of many French bridges. The competition to build the bridge was keen, and Ellet's design was accepted for only $135,000.

In his television series "Civilisation," Kenneth Clark refers to leading engineers of the Victorian period as the great field marshals of the Industrial Revolution. The sobriquet certainly applies with respect to John Roebling. The fame and prominence he achieved were enjoyed by very few engineers. As a result, it is often difficult to sort out fact from fiction with regard to his career. Many of his ideas came from Navier and the French school of bridge design. Roebling was educated in Berlin and became familiar with the work of Navier and the French through translations of Navier's work into German. He was the first to apply Navier's idea of using suspension cables in the design of aqueducts. Since the water in the trunk of the canal is constant and uniformly distributed, a suspension aqueduct with a wooden trunk is an ideal application of the suspension system. Such a structure was far cheaper than corresponding brick, stone, or even iron aqueducts. Roebling's first aqueduct was completed in 1845 over the Monongahela River in Pittsburgh. This was followed by four notable suspension aqueducts completed between 1847 and 1850 for the Delaware and Hudson Canal. This set of five aqueducts was without precedent and epitomized the American approach that prized simplicity, efficiency of construction, and, above all, economy of labor.

Before his work on the Delaware and Hudson, Roebling completed a Gothic revival multi-span structure over the Monongahela River in 1846, using the piers of an earlier timber-covered bridge. With its short interconnected spans with pendulum links at the towers and lack of adequate stiffening trusses, the bridge deflected excessively with moving traffic loads. Nevertheless, it reveals Roebling's concern for architectural style and his first application of combined catenary and stay cable design, which is such a prominent feature of the Brooklyn Bridge. It would have been impossible at the time for Roebling or anyone else to perform an adequate analysis of this indeterminate structure. This lack of a clear theoretical approach did not seem to trouble Roebling in his attempt to provide a stiffer and stronger bridge with a minimum of materials.

In 1847, while Ellet was involved with the construction of the Wheeling Bridge, he was also appointed chief engineer for a suspension bridge across the Niagara Gorge. When he was relieved of responsibility for the latter, the project was taken up by Roebling and completed in 1856. The double-deck highway-railway bridge was unique in the history of this genre (see figure 17). The double-decked design possessed considerable flexural and torsional stiffness with its 14-foot-deep timber trusses. Nevertheless, trains crossed at five miles per hour to reduce any dynamic effects and, as Roebling said, the slow speed "provided a better view of the falls."

The cables were combined into two continuously wrapped wire tendons similar to modern suspension bridges and anchored with Roebling's patented anchorages. The cables were laid up with Roebling's patented wire-spinning method based on Vicat's invention. The purpose was not necessarily to achieve equal stress at each wire but was an expediency in bridge building across a very deep gorge. The towers give a hint of the Egyptian revival style so favored by Brunel. Roebling was to employ Romanesque revival details on his Cincinnati bridge (figure 18), and returned to Gothic for the Brooklyn Bridge (figure 19), following earlier use of this style for his Smithfield Street Bridge in Pittsburgh, completed in 1846.

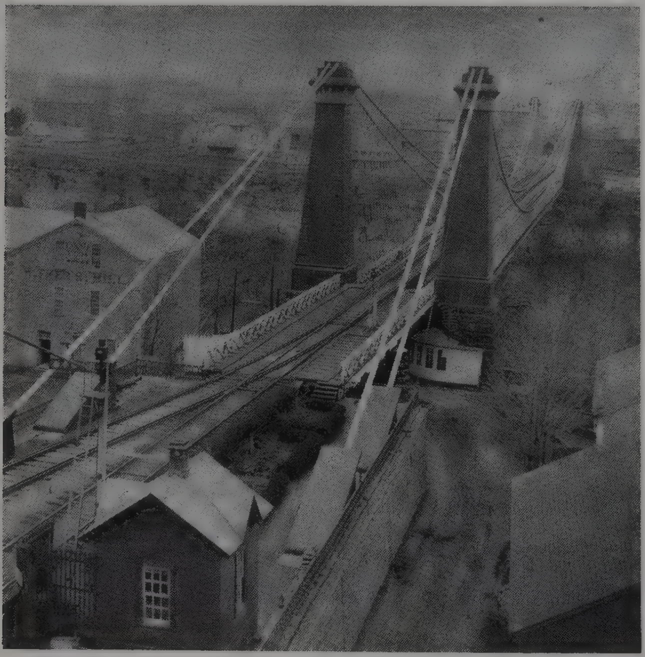


Figure 17. *Roebling's double-deck rail-highway bridge, 1856, over the Niagara Gorge.* Smithsonian Institution.

Conclusions

Both Ellet and Roebling died of injuries before 1870. All of the early British pioneers had died by then also, and the French, following a disaster at an Angers bridge in 1870, placed an interdict on building suspension bridges. Thus the early pioneering period of the modern suspension bridge ends at this date, before the introduction of high-tensile steel wires as a replacement for wrought iron. A more complete history of the early modern suspension bridge can be found in "Links in a Chain—the Development of Suspension Bridges 1801–70."[12]

If one is committed to the idea that the artifact is evidence, then the subtleties of engineering design can readily be discerned by a detailed examination of particular bridges. The information gleaned may not be apparent in the literature or even in the mind of the designer steeped in his national tradition. The Menai Bridge by Telford, the Marlow and Hammersmith bridges by Clark in Britain, and long-span chain bridges at Budapest and Kiev stand as monuments to British engineers and proclaim the virtues of permanence, solidity, and scale of the work, hallmarks of Victorian engineering. The Fribourg Bridge and numerous suspension bridges by the Seguin brothers speak a different language which demonstrates the application of theory to practical engineering design. Thus the French engineers considered every aspect of the design, and the assumptions made are manifest in the structures, where all of the elements are shown.

In many ways, the early American bridges appear more as French derivatives, not because the refinements in design were of primary importance, but because the wire suspension bridge afforded the most expedient and economical solution for long spans. During this period it would have been impossible to secure large fabricated eyebars on the domestic market. Wire, on the other hand, could be very cheaply produced, often at local mills. Not only was wire economical, it had superior qualities because it was cold-worked in

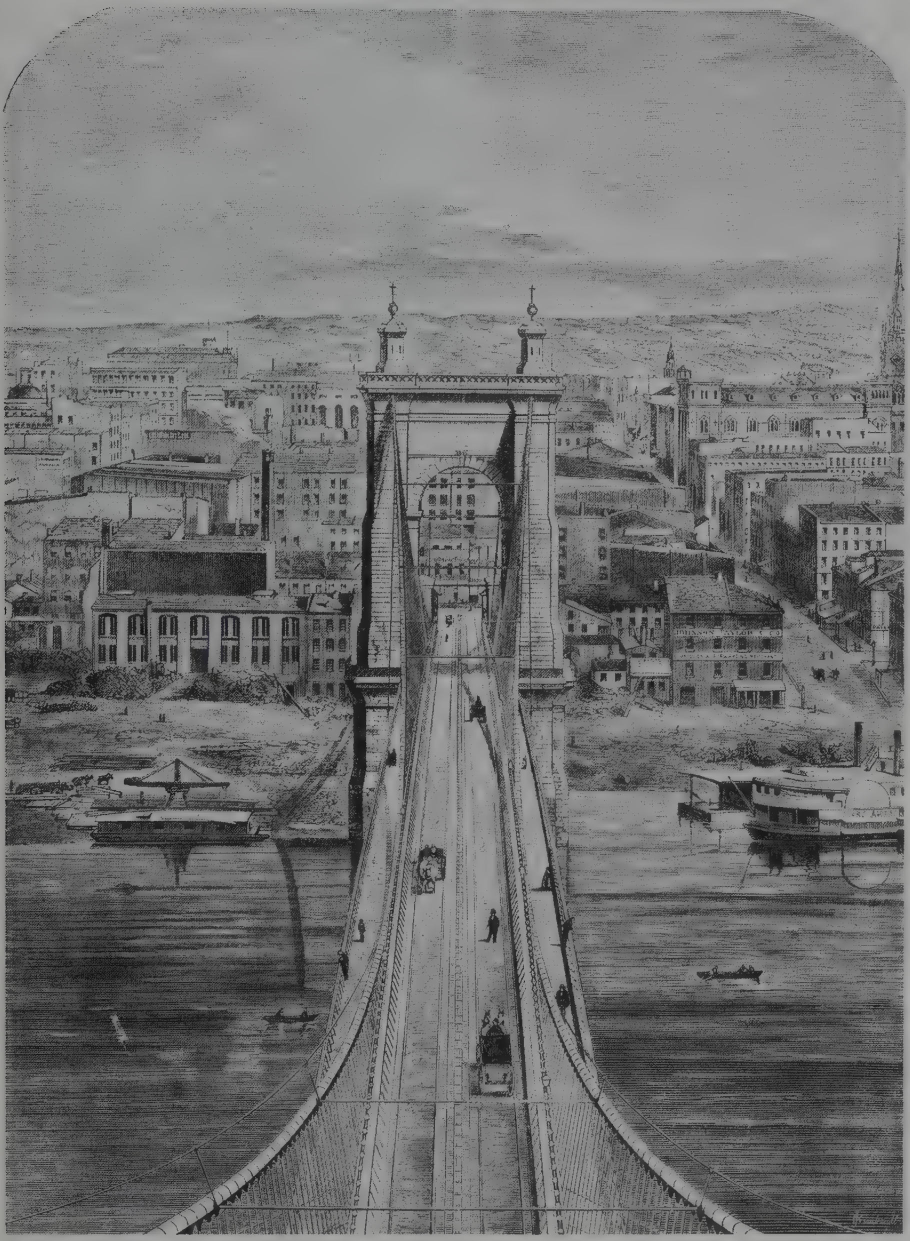


Figure 18. *Roebling's Cincinnati Bridge, 1867*. Smithsonian Institution.

the drawing process, which at the same time tested each inch as it was drawn through the dies. In France as well as America, large eyebars were difficult to obtain, an added reason why wire was the preferred material there. Wire cable proved to be the superior technology and led the way in modern times to bridges with spans approaching one mile in length.

This introduction to national styles in engineering is limited to a case study of 19th-century suspension bridges. At the 1992 Society for the History of Technology meeting held in Uppsala, Sweden, William Withuhn discussed the same theme of national styles with regard to steam locomotive design. He made a convincing case for national styles in France, Britain, and America that reflects the same fundamental factors influencing the design of suspension bridges. Earlier, Thomas Hughes explored the issue with regard to electric power generation and distribution systems.[13] Both authors present a compelling argument for national style in engineering. Thus, the issue is more than aesthetics and

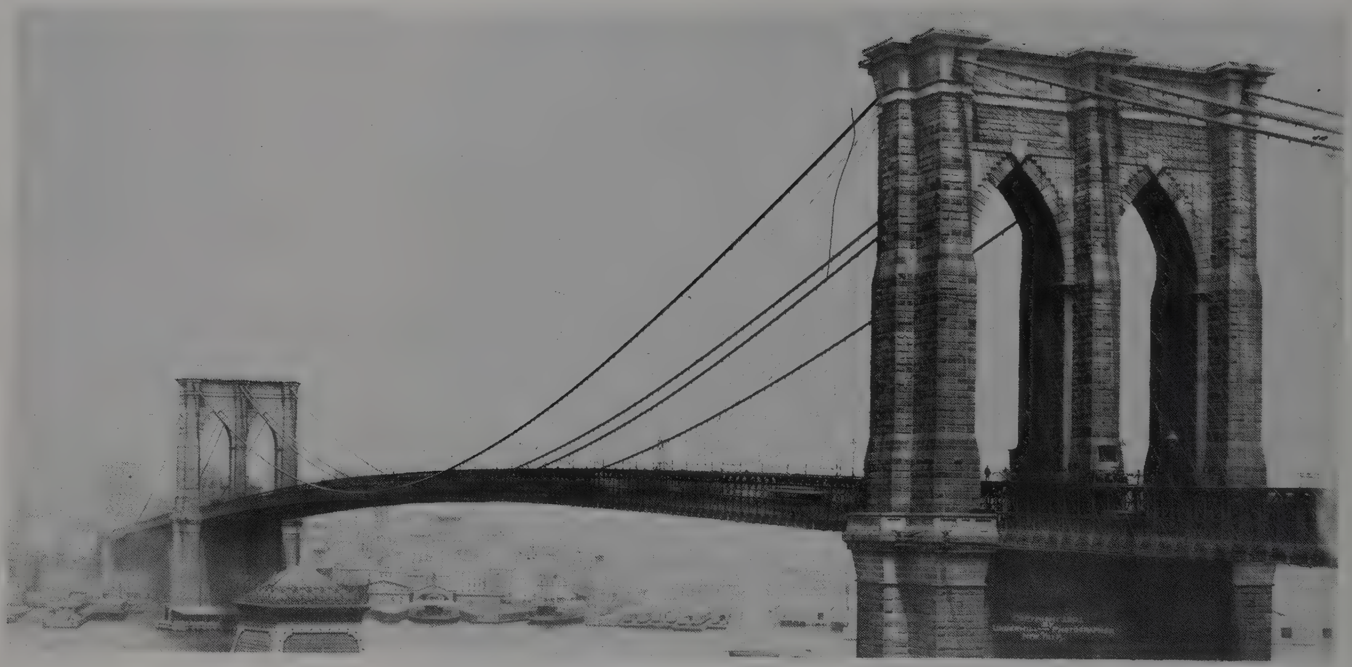


Figure 19. *John and Washington Roebling's Brooklyn Bridge, 1883*. Copyright 1901, Underhill photographer, New York.

architecture; it is at the heart of how engineers design and construct all manner of objects from their own national perspective.

Notes

1. Additional information on the development of professional engineering is in Terry S. Reynolds, ed., *The Engineer in America* (Chicago: University of Chicago Press, 1991), pp. 7–26.
2. The British apprenticeship system and other details of civil engineering practices during the Industrial Revolution can be found in ibid. and W. H. G. Armytage, *A Social History of Civil Engineering* (London: Faber & Faber, 1961), pp. 138–152; and Hans Straub, *A History of Civil Engineering* (Cambridge, Mass.: MIT Press, 1964), pp. 163–219. Reynolds is the most complete treatise on the subject of American engineering and its relationship to both British and French traditions.
3. For the work of British and French engineers in the construction of suspension bridges, see H. J. Hopkins, *A Span of Bridges* (Newton Abbot, England: David & Charles, 1970), pp. 174–236; quotation on p. 187.
4. Finley's remarkable invention is discussed in James Finley, "A Description of the Patent Chain Bridges," *Portfolio* 3, 6 (1810):448.
5. Thomas Pope, *A Treatise on Bridge Architecture* (New York: Alexander Niven, 1811).
6. E. L. Kemp, "Samuel Brown: Britain's Pioneer Suspension Bridge Builder," in *History of Technology*, ed. A. R. Hall and Norman Smith (London: Mansell, 1977), p. 12.
7. L. J. Vicat, "Ponts Suspendus en Fil de Fer sur la Rhone, Rapport," *Annales des Ponts et Chaussées* 1 (1831), and Vicat, "Observations Diverses sur la Force et la Durée des Câbles en Fils de Fer," *Annales des Ponts et Chaussées* (Mémoires et Documents) 11 (1836):206.
8. Charles Ellet, Jr., *Report of the Wheeling and Belmont Suspension Bridge* (Philadelphia: John Clark printer, 1847).
9. Charles Ellet, Jr., *Report on the Mississippi Bridge* (Philadelphia: William Slavely & Co., 1840).
10. E. L. Kemp, "Ellet's Contribution to the Development of Suspension Bridges," American Society of Civil Engineers *Engineering Issues—Journal of Professional Activities* 99, PP3, paper 9872 (July 1973):331; and Clifford M. Lewis, "The Wheeling Suspension Bridge," *West Virginia History* 23, 3 (April 1972):221.
11. David Stevenson, *Sketch of the Civil Engineering of North America* (London: John Weale, 1838).
12. E. L. Kemp, "Links in a Chain—the Development of Suspension Bridges 1801–70," *The Structural Engineer* 57A, 8 (August 1979).
13. Thomas Hughes, *Networks of Power* (Baltimore: Johns Hopkins University Press, 1983).

Elephant under Glass: The Piano Key Bleach House of Deep River, Connecticut

David H. Shayt

The industrial fabrication of elephant ivory consumer goods is rapidly entering the world of lost arts. Both the markets for ivory wares and the specialized skills and tooling used to produce them are vanishing beneath a new worldwide concern for the survival of elephants. Among the procedures unique to ivory processing, the sun-bleaching of piano keys occurred at the midpoint of a slow, multi-stage transfiguration of elephant tusks into the thin wafers of key veneers. One ivory-specific structure—a piano key bleach house—survives in North America to recall the inner workings of this process, and the outer global transformation in attitudes toward the industrial uses of natural versus synthetic materials.

Unlike the majority of primary industrial processes that add or remove material from products prior to their finishing and assembly, the bleaching of piano ivories was entirely a cosmetic procedure. By the time the ivories reached the bleach house (figure 1), they had already taken on the dimensional attributes the pianist would rely on at the keyboard. Tradition, however, dictated that the ivory-white surface look precisely the same from key to key, display a minimum of grain, and be free of blemishes of any sort.

Surrounding this starkness were the highly figured, multi-hued woods in the casework of upright and grand pianos. Such counterpoint, embellished by a row of jet black raised keys, expresses an abiding philosophy of commercial marketing: however the package may change or the function differ, certain primary elements of a product line must remain constant and easily recognizable.

This historic allegiance to colorless keys over the course of several centuries and many upheavals in piano design and musical taste has given industry the seemingly simple task of maintaining a plain product's customary look. The peculiar surface texture and porosity of ivory further simplified production options by confounding the adoption of ersatz key materials. But the problems inherent in the acquisition and working of elephant ivory dogged and ultimately doomed the craft, one that nevertheless reached high levels of technological artistry and discipline due to the unwavering consistency demanded in the final product.

The American Ivory Industry

Prehistoric artisans carving with stone tools on the tusks of Ice Age mammals began a relationship with ivory that has continued almost to the present day. The sympathetic ways in which the large teeth of certain animals have interacted with cultural groups the world over and with cutting tools have produced over the last several thousand years a rarely interrupted flow of new artworks and utilitarian devices. Ivory's toughness, size, and radiance have distinguished it from bone, horn, shell, or any other natural substance and continue to defy replication by synthetics manufacturers.[1]

Ivory is a form of mineralized tissue called dentine, found in its purest states in the tusks or projecting front teeth of the elephant, the hippopotamus, the warthog, and the walrus. Other mammals such as the grizzly bear, sperm and killer whales, narwhal, and now-extinct saber-tooth tiger, mammoth, and mastodon also have yielded up teeth to the ivorycarver, chiefly for the creation of small works of religious or tribal importance. The durability of ivory and the ferocity of the animals from which it was taken have given ivory a special, almost spiritual, meaning to many preindustrial cultures.[2]

In North America, walrus tusks and the teeth of sperm whales received the bulk of ivoryworking attention from North Atlantic and Arctic maritime communities. Carvers often left unaltered the original tusk or tooth profiles and oval cross-sections, restricting themselves to the incising or scrimshawing of thematic images into the outer surfaces. With few exceptions, such work was produced by self-taught folk artists associated with the hunting of whales and walrus, creating portable totems of the manly vanquishing of great beasts. This folk tradition reflects the historic symbolic uses of ivory as a trophy. Conversely, the American ivoryworking industry would look solely to the internal physical properties of ivory as raw material.[3]

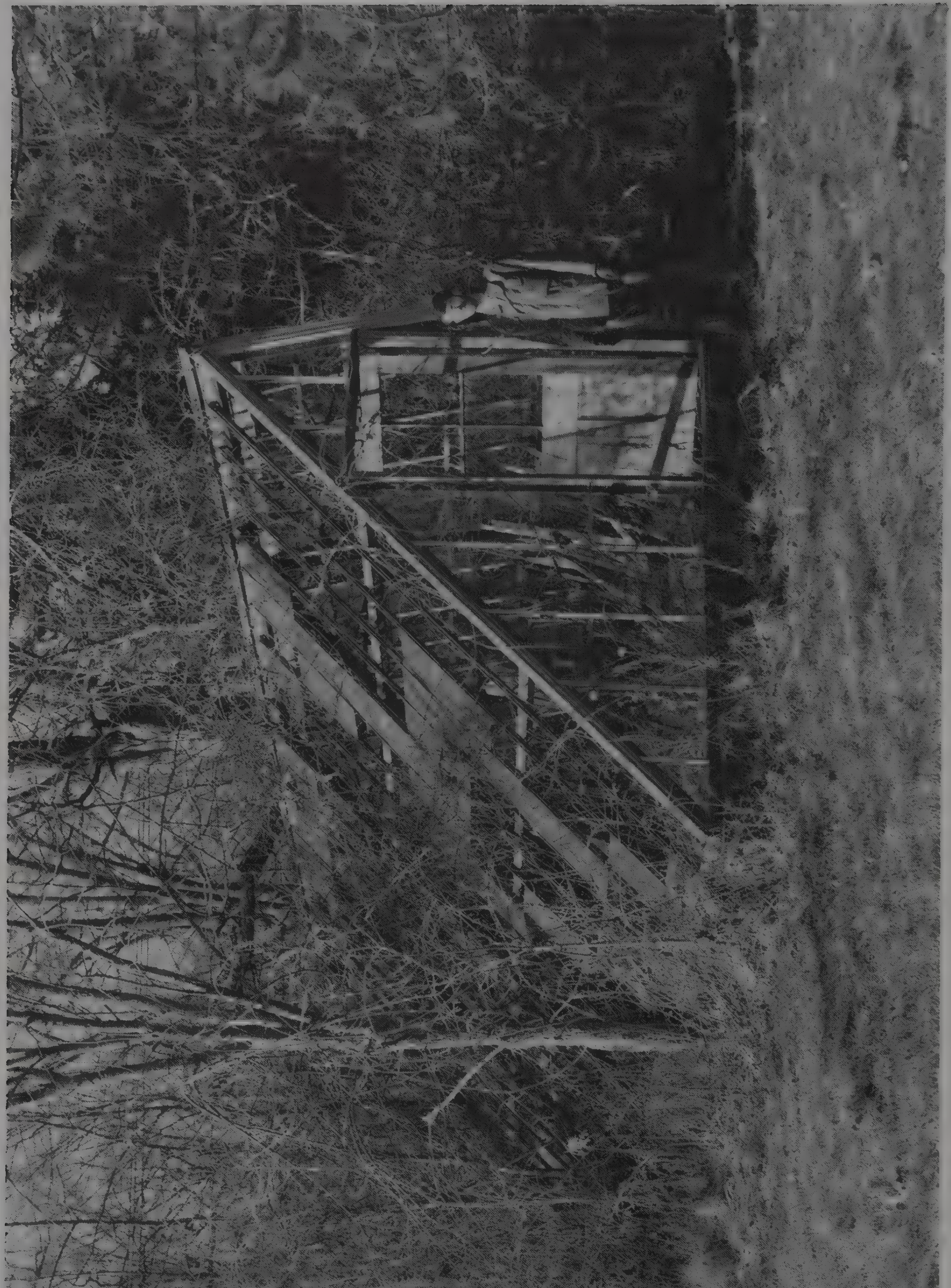


Figure 1. *The embowered Deep River bleach house, December 1988.* Photograph by the author.

Elephant tusks contain the most significant concentrations of workable ivory, both in cross-sectional area and in performance. Little record, however, exists of North Americans working either African or Asian elephant ivory prior to the 1790s, although slave ships were known to return from West Africa carrying tusks. New England traders in the West Indies, and later in Africa, obtained ivory when available, together with copra (a source of coconut oil), cloves, hides, copal (tree resin used as a varnish), and other precious African extractions.[4] The ivorycarvers listed in 18th-century New York and Philadelphia business directories do not disclose whether their material derived from land or marine mammals. Regardless, markets and means of production in this luxury medium were insufficient to make the work in this period anything more than a specialty handcraft.

As with steel and other precious commodities, ships from Europe brought the first finished elephant-ivory combs, cutlery handles, walking sticks, and chessmen to the New World. And as with steel, American innovators persistently sought methods to mechanize sufficiently to seize the manufacturing advantage once reliable supplies of quality raw material could be secured.

Patents, business records, and local lore tell of the Pratt family, mill owners in the lower Connecticut River valley. They perfected waterpowered machinery in the early 19th century to cut the fine, needle-like teeth in ivory combs that were formerly cut by handsaw.[5] The factory manufacture of combs, clockworks, buckets, and numerous other specialty products had its origins in the hardwoods of New England forests. Located between major urban markets, the trade-centered villages of Connecticut and Massachusetts were thus well-positioned technologically to adapt to the slightly harder tusks, tortoise-shell, and brass plate when these uncommon but fashionable substances first became available in quantity.

The evident success of the Pratt comb-sawing enterprises helped transform the small mill villages around the port of Essex into the ivoryworking center of the continent. The logical preference to make commercial use of the full extent of a tusk's workable ivory spread production from combs (figure 2) to teething rings and other small notions to paper folders to billiard balls and to piano keys, exhibiting corresponding patterns of increasing mechanization and labor subdivision.[6]

Family dynasties of Pratts, Reads, Comstocks, and Cheneys arose in the region to dominate ivory factory ownership and the towns of Deep River and Ivoryton (figure 3). All local operations consolidated in 1936 when Ivoryton's Comstock-

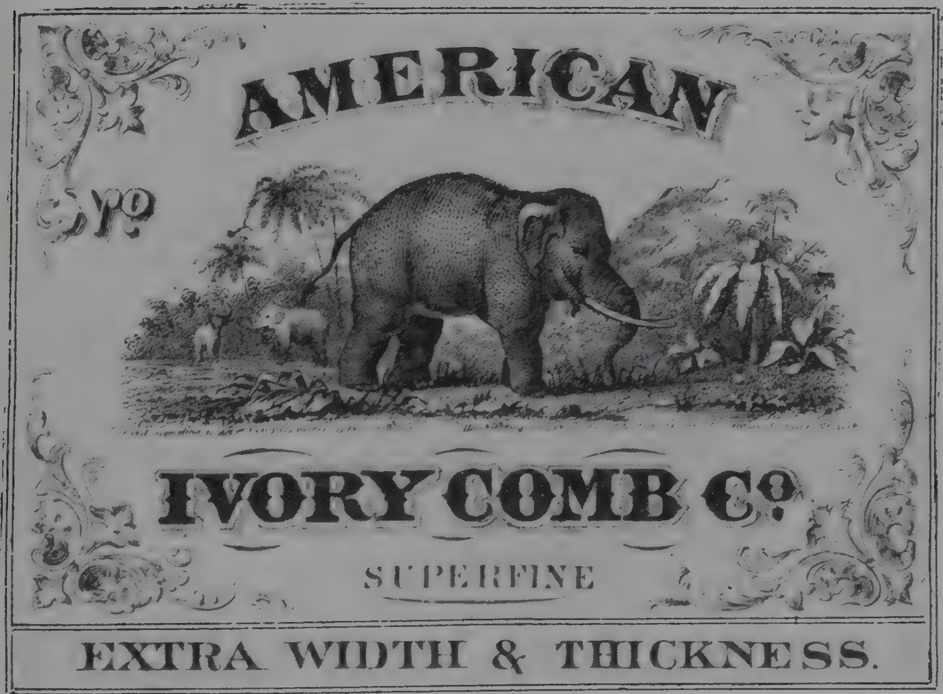


Figure 2. *Connecticut comb box label, 1880. The scene incorrectly depicts Asian elephants as the source of the factory's African ivory.* Pratt-Read Corporation Records (320), Archives Center, National Museum of American History, Smithsonian Institution.

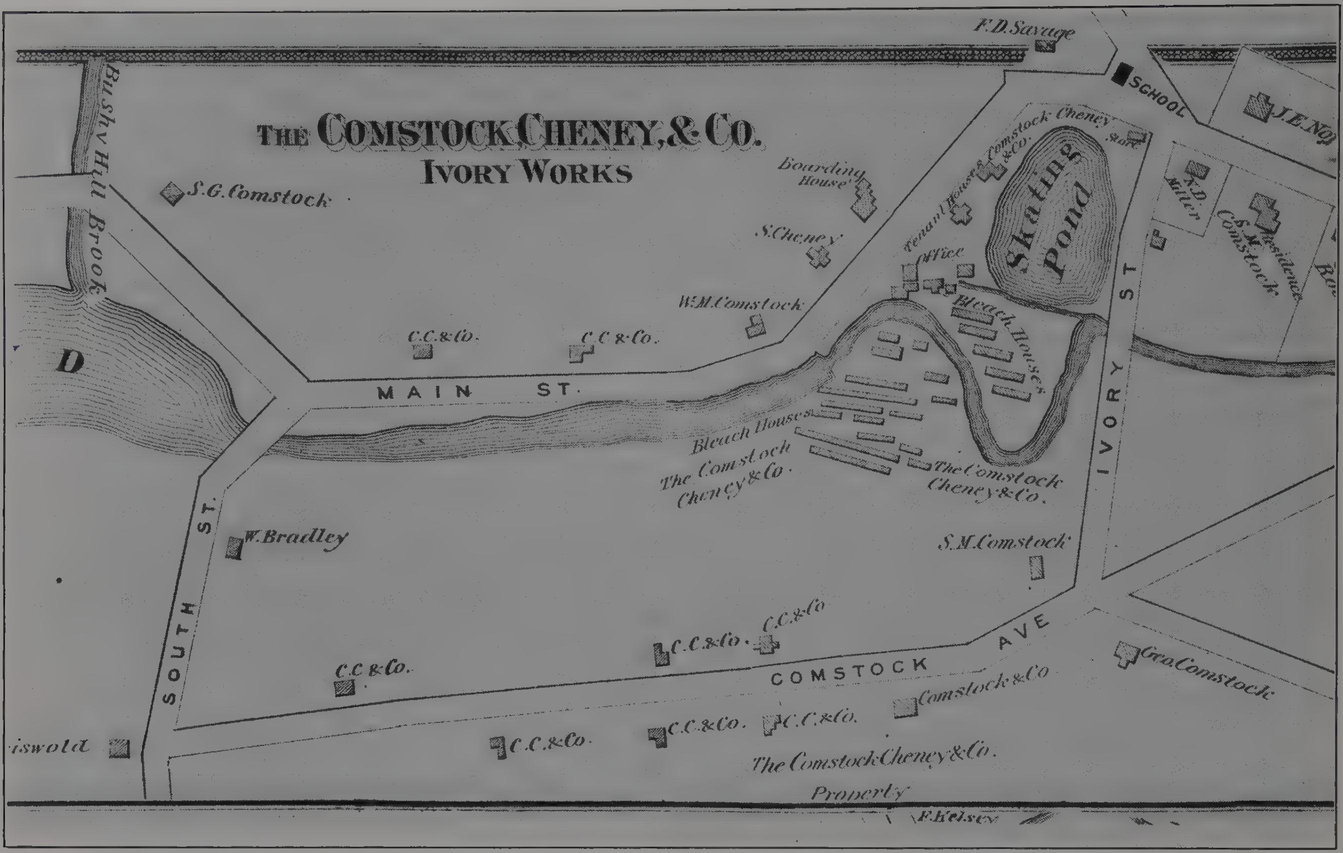


Figure 3. *The company town of Ivoryton, Connecticut, looking north, 1860s. Note pervasive Comstock, Cheney presence and south-facing bleach houses.* Detail from F. W. Beers, *County Atlas of Middlesex, Connecticut* (1867). Pratt-Read Records.

Cheney works merged with Deep River's Pratt-Read concern under the latter's more established name in the piano industry. Ivoryworking districts also flourished in lower Manhattan, Newark, and Buffalo, but the flowering of the industry took place in rural communities 30 miles north of New Haven, judging from the concentration of fully integrated factories, the regional profusion of ivoryworking patents, and the rise of an ivory culture among the townspeople.[7]

At the height of the trade (roughly 1850 to 1940), tusks would arrive in New York from ivory buyers stationed by American importing houses in London, Antwerp, or the East African ivory depots of Mombasa and Zanzibar. At their source, the companies relied on itinerant elephant hunters and local merchants for the stock, declining cracked and diseased tusks and buying by weight (figure 4). After additional grading in New York, tusk shipments were loaded on coastal schooners for the trip to Essex and then traveled by wagon to the factories (figure 5).

In a 28-year-period (1884–1911), over 4,900 tons of unworked elephant ivory entered the United States, principally to be machine-cut into small-instrument handles, measuring tools, billiard balls, and piano keys. Prices paid in New York varied from $1.80 to $4.00 per pound, depending on grade and availability. No more than four or five billiard balls could be turned from the average adult African tusk, while the same tusk might yield 50 to 55 complete piano keyboards, roughly 5,000 separate slips of ivory.[8]

The creamy ivory from the lesser tusks of the Asian male elephant was considered especially well-suited for small jewelry and game pieces, but the more plentiful African species—both male and female—produced the largest tusks

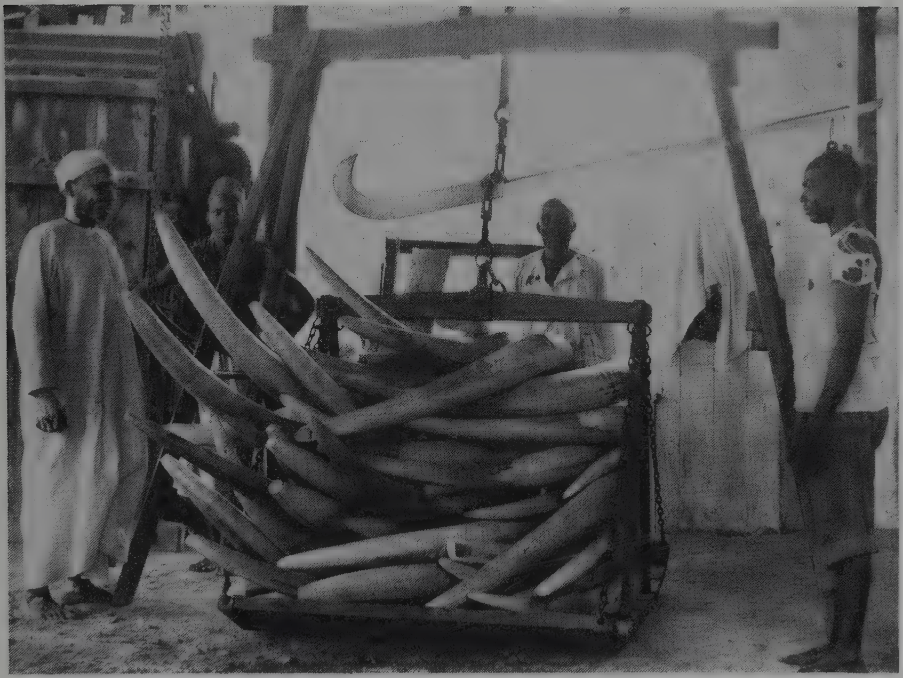
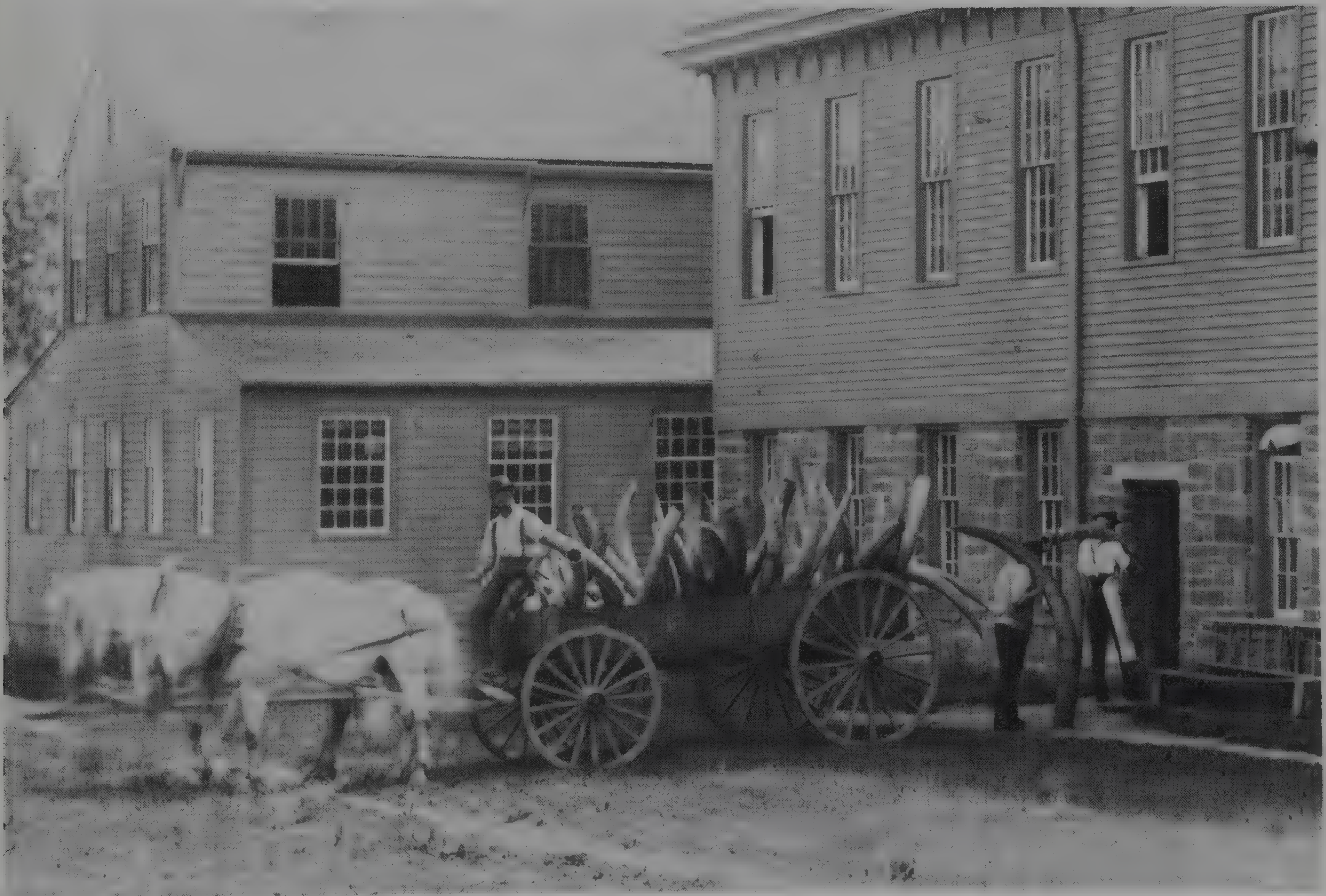


Figure 4. *Tusks on a Fairbanks (Vermont) scale in Zanzibar, 1910.* Ernst D. Moore Collection (321), Archives Center, National Museum of American History, Smithsonian Institution.

Figure 5. *Off-loading tusks at Comstock, Cheney & Co., Ivoryton, 1890. Both buildings survive intact and in use.* Pratt-Read Records.



at maturity. Lengths could reach 10 feet, with diameters up to eight inches. Regional variation across Africa also was considerable, as one German ivory manufacturer explained in a trade booklet distributed at the 1876 Centennial Exhibition in Philadelphia:

> Soft or white ivory is the chief produce of Eastern Africa: from Egypt down to the Cape. It is particularly well adapted for making combs, pianoforte keys and billiard balls. Hard or transparent ivory is nearly all imported from the West Coast of Africa, the Gaboon and Ambriz districts yielding the most superior quality, while shipments from Angola and Lagos shew a coarser texture. It is used for knife-, stick-, and umbrella handles, carvings of all kinds: such as crucifices, statuettes . . . and covers for prayerbooks, fans etc.[9]

Beyond its genetic origins, the active nature of ivory's chemical microstructure renders this material highly responsive to sudden changes in humidity and light levels after it leaves the elephant. Once opened up and stripped of its husk or protective outer layer, discoloration and cracking readily occur if care is not taken in storage and handling.

Among ivory's many decorative and functional uses, piano keys offered the Connecticut ivoryworkers their most lucrative challenge in coping with the volatility of ivory and with the American piano industry, centered in Boston and New York. Although ivory served only as the thin veneer layer at the user end of the complex wooden key action, the largest of the ivory factories ultimately produced the full wire-striking mechanism and in some cases crafted the entire piano. Ivory knowledge, however, remained the region's chief distinction.

The Piano Key

Builders of the earliest European keyboard instruments—spinnets, virginals, clavichords, and harpsichords—employed an array of tough, glossy materials to finish their keys, the all-important meeting ground of musician and machine, art and technology, thought and muscle. Nuanced interpretations of keyboard musical scores traditionally have relied on the touch of the player's fingers to transmit suitable pressure indirectly through a series of lever actions to the piano wire. Basswood and various fruitwoods were early favorites as key material, either for the broad lower keys (the naturals) or the narrow raised keys (the sharps). One or the other typically was dyed black to readily distinguish between the two key sets. Ebony wood quickly caught on as a close-grained key material for the naturals, requiring little artificial blackening.[10] Both ebony and ivory were among the prize commodities to be won from Africa when vast territories were claimed or colonized by Europe in the 18th and 19th centuries. Ivory's greater scarcity limited it initially to the tops of the sharps. Whether due to the opening of African trade routes by Great Britain in the 18th century or a general feeling that black piano keyboards seemed ill-suited to the newly written works of Hayden, Mozart, Beethoven, and Schubert, British pianomakers emphatically shifted ivory to its present dominant place atop the naturals.[11] Mainland European makers followed, both with greater access to African trade and with ivory naturals. Supplies never were sufficient to construct keys entirely of solid ivory; thin (1/16th-inch) veneers glued to close-grained woods remained the standard, although the sharps were of solid ebony.

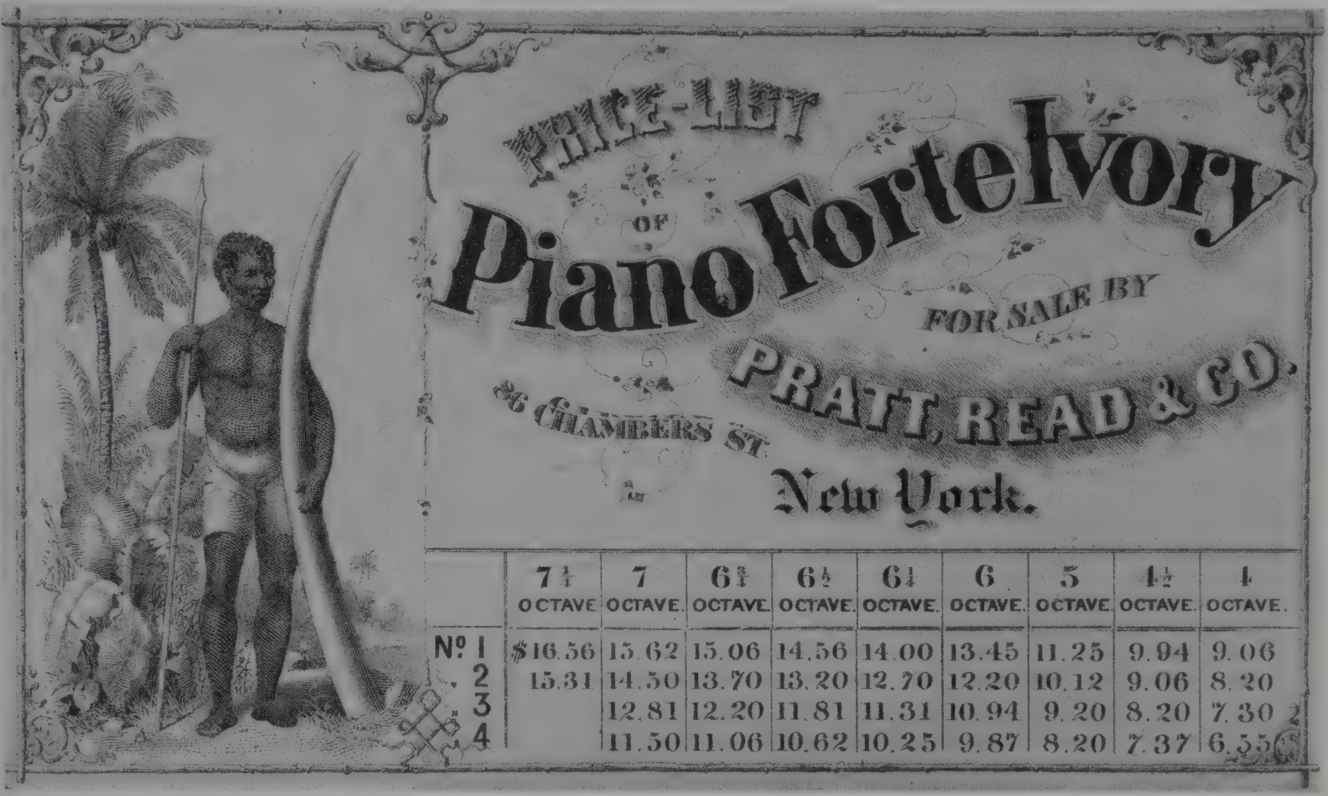
Among North American builders, the choice among key materials was not yet so self-evident, according to one judge at New York's Crystal Palace exhibition in 1853:

> The necessity of Schools of Art and Design among us is exhibited in not a few instances, in the vulgar, tawdry decorations of American pianos, which show a great deal of taste, and that very bad. Not only do we find the very heroics of gingerbread radiating in hideous splendors, fit for the drawing room of a fashionable hotel, adorned with spit-boxes among other savageries; but even the plain artistic black-and-white of the keys—that classic simplicity and harmonious distinction—is superseded for pearl and tortoise-shell and eye-grating vermilion abominations. The Committee would advise the makers of these latter instruments to keep them exclusively for the Shanghai trade.[12]

Such condemnations were not lost on the larger American manufacturers like the Steinways in New York and Jonas Chickering in Boston who already were using ivory. Connecticut ivory-bleaching patents of the 1850s cover specific treatments for speeding and enhancing the whiteness of piano keys.[13] Wrapped packs of piano key ivories were marketed by the Connecticut factories well before they expanded into the production of the entire key assembly (figure 6).

Close scrutiny of the ivory keyboard reveals two and occasionally three ivory components to every key: the short, wide head struck by the fingertip; a long, narrow tail extending back between the sharps; and among certain builders, the key's vertical front or face beneath the head's nosing. The head and tail are butted together where the sharps begin, producing a fine but unmistakable hairline across the ivory keyboard (figure 7).

Economy and breakage dictated this two-piece configuration, the 1/2-inch by 4-inch tails glued left or right above 1-inch by 2-inch heads to form the full eight-key octave. Wastage would have been considerable and excavation from



PRICE-LIST
OF
Piano Forte Ivory
FOR SALE BY
PRATT, READ & CO.
36 CHAMBERS ST.
New York.

	7¼ OCTAVE.	7 OCTAVE.	6¾ OCTAVE.	6½ OCTAVE.	6¼ OCTAVE.	6 OCTAVE.	5 OCTAVE.	4½ OCTAVE.	4 OCTAVE.
Nº 1	$16.56	15.62	15.06	14.56	14.00	13.45	11.25	9.94	9.06
2	15.31	14.50	13.70	13.20	12.70	12.20	10.12	9.06	8.20
3		12.81	12.20	11.81	11.31	10.94	9.20	8.20	7.30
4		11.50	11.06	10.62	10.25	9.87	8.20	7.37	6.55

Figure 6. *Price list for pre-cut sets of key ivories, eight keys per octave, 1860s. Grades at left refer to the grain: the less pronounced, the better the grade and the higher the cost*. Pratt-Read Records.

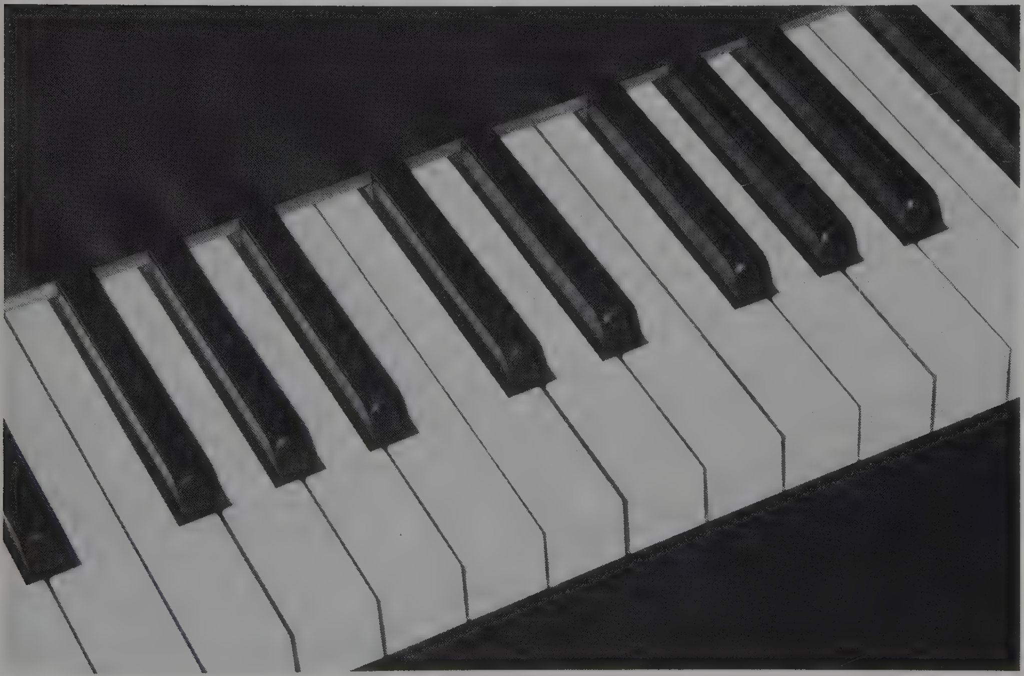


Figure 7. *Ivory keyboard detail, American grand piano, 1880s.* Photograph by the author, 1993.

the tusks very tedious if key tops were not simple two-piece rectangles but long one-piece L-shapes and T-shapes cut to fit around the sharps. In addition, the inherent brittleness of ivory would have made the right-angle cut a center of stress prone to fracture during manufacture and usage were the head and tail not separate. The two-piece arrangement also made head replacement easier if damage did occur after attachment to the keyboard.

The true head-tail genesis may have had more to do with the early scarcity of quality ivory in Europe, when maximum use was made of each available chunk. This dimensional standard nonetheless remains a signature of ivory keys, distinguishing them from the seamless white materials that followed. Two important exceptions are the mammoth-ivory key (fabricated in Germany today from Siberian tusk) and the American cow-bone key (manufactured in Rhode Island from bovine femurs, principally for pipe organs). The scarcity of high-quality bone and mammoth ivory, and the costs involved in their fabrication into heads and tails, may limit wider applications.[14]

American ivory-goods manufacturers—chiefly the billiard ball makers—began calling for a replacement ivory as early as the 1870s, when the quality and quantity of elephant-tusk imports began to show signs of uncertainty. Celluloid piano keys, first appearing late in that decade, were one of the first trial applications of a faux ivory. Striated celluloid could be fashioned to simulate ivory's grain, but pianos with such keys rarely rose above the cheaper mail-order instruments at the lower end of the market. As Robert Friedel has observed in chronicling the difficult early years of this material, imitation never fully matured into substitution as long as both status and performance remained the exclusive domains of ivory.[15] Celluloid eventually found favor with some prominent pianomakers as a thin facing material for the unfingered fronts of the piano keys. But ivory's dominance on the piano clearly was not just a matter of appearance. Many concert pianists have maintained to the present day a preference for the smooth but slightly tacky, moisture-absorbing feel of ivory. In a 1931 issue of *Scientific American,* one Connecticut ivory man summed up the sensorial attraction ivory holds for piano players: "It is yielding to the touch, yet firm; cool, yet never cold or warm, whatever the temperature; smooth to the point of slipperiness, so that the fingers may glide from key to key instantly, yet presenting just enough friction for the slightest touch of the finger to catch and depress the key and to keep the hardest blow from sliding and losing its power."[16]

Bleaching Ivory

As a primary attribute, the ivory key's distinctive hue exists neither uniformly throughout the tusk nor is it easily standardized once the raw ivory has been worked. Gradations of white, from mottled yellows and grays to faint reddish browns can occur naturally, depending on the elephant's diet, genetic inheritance, and state of health. Ivoryworkers in industrial Connecticut sought to mitigate such variation by employing bleaching regimes more commonly associated with the bleaching of textiles and human hair.[17]

Sun-bleaching supplemented chemical solutions once it was discovered that sustained daylight and heat would both whiten ivory and accelerate the activity of the liquid bleaching agent. Deprived of light over an extended period, ivory darkens to an amber brown. The actual mechanism within the ivory that triggers such color changes is little understood, judging from the industry's near-total reliance on empirical testing.

One clue comes from a distant but not unlikely source. In recent decades, the bleaching of discolored teeth has become a dental option for fashion-conscious Americans.[18] The dentine or ivory in human teeth is protected by a hard enamel and has a less intricate microstructure than in elephants, but the chemical makeup is identical. Dental bleaching services, stain removal, and whitening techniques typically involve applications of a 35-percent hydrogen peroxide solution activated by 30 minutes beneath a high-intensity heat lamp set between 115 and 160 degrees Fahrenheit. The technique is capable of bleaching up to 10 frontal teeth in three sittings.[19]

Post-bleaching dental studies suggest that light-sensitive molecules causing discoloration within the teeth are released through the photooxidation that occurs during bleaching, when the bonds with non-colored or "white" molecules are weakened or broken. But the living connective tissues in human teeth appear to regenerate the problem molecules and usually produce a color reversal in bleached teeth after a few weeks.

Ivory for piano keys was cut only from the interior layers of the extracted elephant tooth, an area that exhibits considerable variation not only in hue but in grain patterns. A second goal of ivory bleaching, therefore, was to minimize the visibility of grain, in turn minimizing key-to-key variation.

Unlike the growth rings in wood grain, the apparently two-dimensional grain of ivory is largely an optical effect caused by the incidence of light striking varying depths of an intricate tubular canal system that grows progressively outward from the tusk's pulp chamber. The luminescence of finished ivory derives from this mineralized but seemingly liquid network of three-dimensional gelatinous fibers. In cross-section, these serpentine canals take on the interwoven appearance of machined knurlings or the "engine turnings" cut into ornamental pocketwatch cases by the tooling of European rose engine lathes[20] (figure 8).

Within the scientific community, the unique crosshatching of elephant ivory is termed the Schreger pattern, after the German researcher who first described this figuring in 1800.[21] The lines increase in definition and their weave opens up as they approach the perimeter of the tusk, suggesting that progressive structural weakness also occurs as the ivory moves outward from the center.

On the piano keyboard, unlike virtually all other ivory arts, these undeniably beautiful traits were regarded as visual distractions and liabilities, either in transverse section or longitudinally. This preference for grainlessness contrasts with the swirling mahogany, oak, and walnut veneers selected for the piano's surrounding casework. The downgrading or outright elimination of keys with visible grain

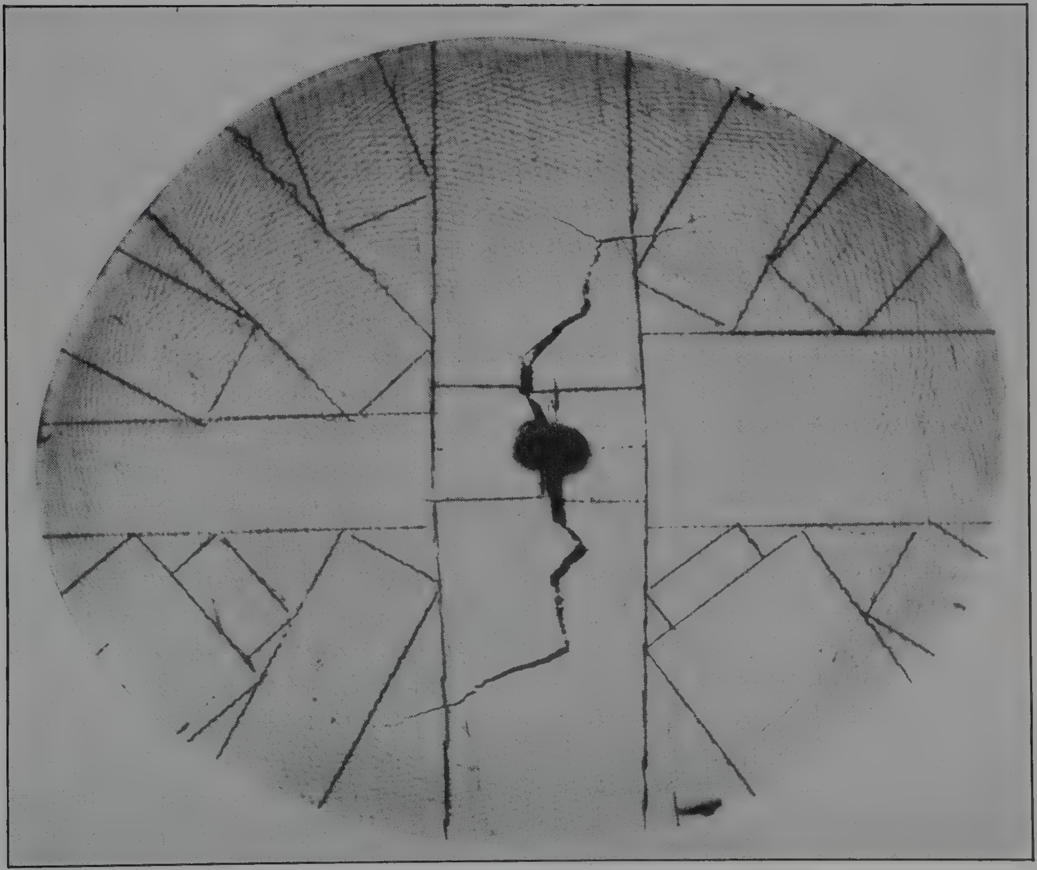


Figure 8. *Tusk cross-section, full-size, showing interwoven Schreger lines, overlaid by blocking layout for piano key heads and tails. All face the center to minimize non-symmetrical grain. The fracture growing outward from the pulp cavity suggests that excessive drying occurred after blocking.* From "The Romance of the Ivory Piano Key," *Piano Trade Magazine*, March 1925, p. 62.

was dependent largely on the actions of the bleach house and, at a later stage, the matching table. This importance of grain will be revisited in the description of the matching process.

The Bleach House

The ivory industry's signal contribution to architectural history certainly is the freestanding, knife-edge bleach house. Rank upon rank of these long, prismatic structures lined the hillsides around Deep River and Ivoryton. In all other respects the surviving ivoryworking factory buildings are the typical 19th-century brick two-to-four-story, open-bay, high-window rectangles found across the industrial landscape.

The main Pratt-Read factory in Deep River, built in 1881, is now the Piano Works condominium complex. The unexceptional ivoryworkers' company houses that remain in rows along the side streets are owner-occupied today, many considerably modified with add-ons. But on Main Street near the Kelsey Hill Road turnoff, inside a dense stand of low trees and underbrush, is the rusted semi-windowless bleach house (figure 1).

That the only survivor of this species has been taken over by vegetation is not altogether inappropriate. In the late 1920s local resident Joseph Suda purchased this 31-foot segment of what was probably a much longer structure and transported it from the Pratt-Read plant at one end of Main Street to his farm at the other end, where it served as a greenhouse into the late 1970s (figure 9). Thus it rejoins in afterlife the global family of glasshouses better known for their connections to flowers, trees, and world expositions. The 18th- and 19th-century cast-iron conservatories, orangeries, arcaded winter gardens, crystal palaces, hothouses, and domed glass pavilions of Europe and North America enjoy a special jewel-like stature in the world of architecture. Their graceful webs of cast iron produced fantasy-like atmospheres of outdoor wonder in indoor comfort. None of the historians of glass architecture, however, have yet discovered the ivory bleach house, a distinct although non-public subspecies of this transparent family.[22]

Until a devastating flood swept through nearby Ivoryton in 1982, a second, larger bleach house, on its original Comstock-Cheney factory site (figure 10), survived the 1950s dissolution of the local ivory industry. The flood or its aftermath of demolition did away with this in situ example, featured in Connecticut's statewide inventory of historic industrial sites.[23] No further effort at recording or landmarking seems to have taken place.

The primary face of the surviving bleach house descends at a 45-degree angle from a height of 11 feet. Rolled steel bars bolted to angles and channels make up the framework. Fixed window sashes on the primary face held 60 panes of glass, each 18 inches wide by 50 in height. This furnished space for 120 of the sawtooth zinc head racks (two racks per pane, each holding 200 heads) or 60 tail racks (82 tails per rack).

The rear glass wall slopes buttress-like 10 degrees from the

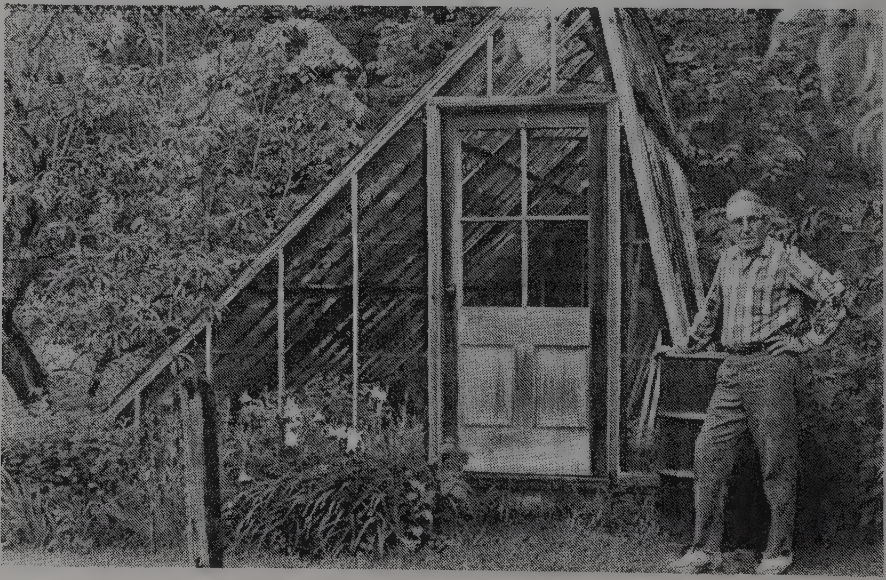


Figure 9. *The reincarnated bleach house, with second owner Frank Rodamer*. From Saybrook, Connecticut, *Pictorial Gazette*, June 21, 1977, p. 10.

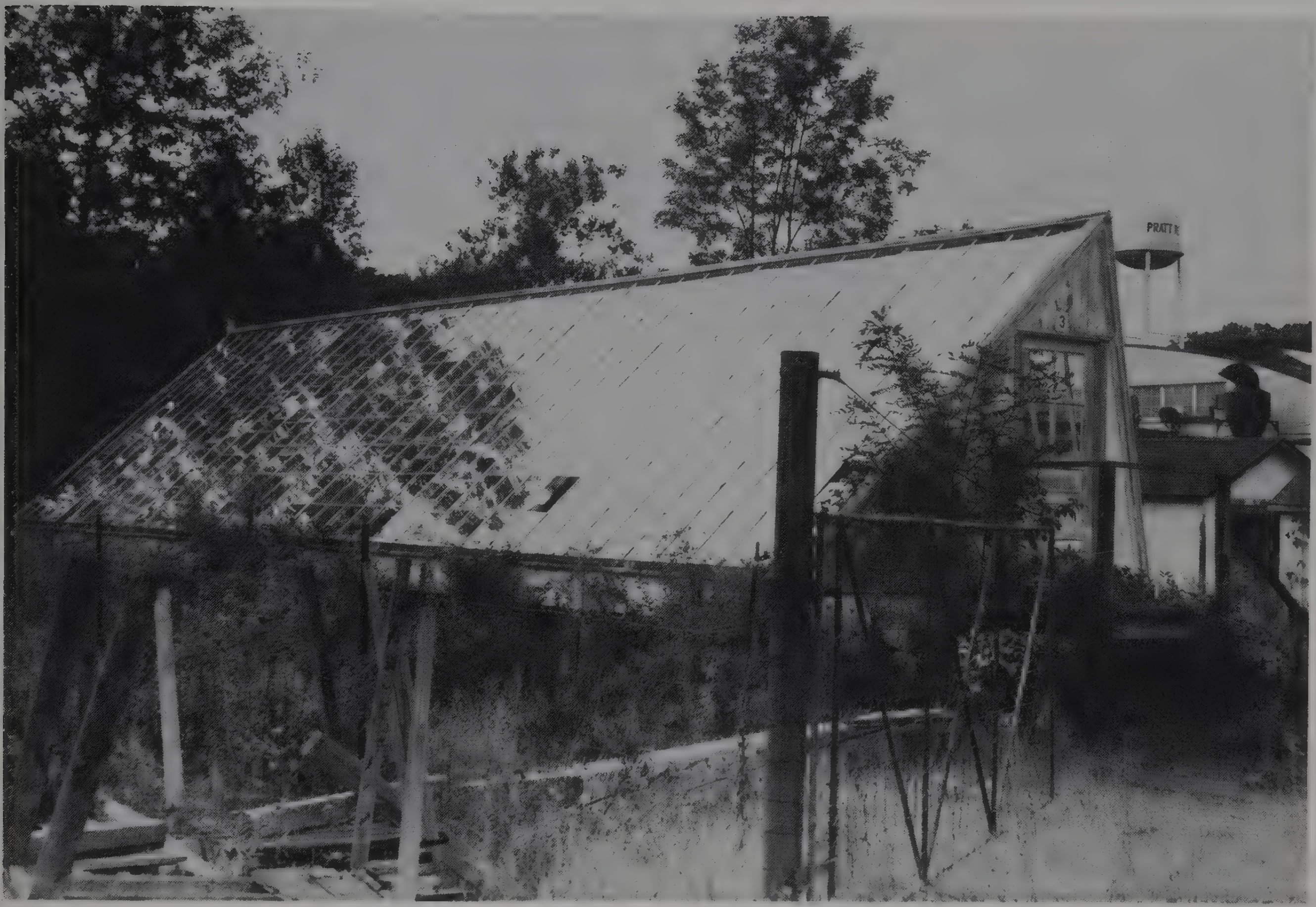


Figure 10. *Ivoryton's last bleach house, 1970s, derelict but sound, later to be the victim of a 1982 flood.* Pratt-Read Records.

vertical and, together with the glass side walls, admits indirect side light to prevent shadow lines from falling on the keys racked in the main face. The interior space, 12 by 31 feet, has lost the steam lines that would have kept the house at a uniform humidity and temperature (100°F), but the original hand-geared vent windows along the top of the back panels remain, although rusted fast. Suda appears not to have required the flooring, planting his greenery in the soil enclosed by the structure's walls.

The wall base plate, a nine-inch inverted rolled channel, is bolted beneath the front and back and along one side panel. Anchor bolts run through this channel into a shallow concrete foundation. Along the fourth side, a channel seems never to have existed, and a two-by-eight-inch timber carries the glass side wall. This, together with the rough-cut channel ends (figure 11), suggests that this structure is a section amputated from the end of one of the more typical bleach houses 400 to 600 feet in length.[24]

Except for length and the lack of a floor, the Deep River bleach house incorporates the features typically found in the surviving drawings and photographs of these modest structures. Their scale and construction were suited entirely to their single-use purpose. They were free of ornamentation and just tall enough to admit a worker with hands stretched overhead to place a rack of ivory in the topmost windows.

Functionally, they were cousins of the slant-roofed glass orangeries and peacheries of 18th-century English manor houses and the 19th-century glass-walled American photographic printing studios, both types usually mated along their back length to larger buildings in place of a rear wall.[25] In rows, the bleach houses might be mistaken for sawtooth monitor roofing over some vast subterranean factory.

The Connecticut bleach houses were space frames, easily supporting their own light weight without the addition of roof trusses, columns, or beams. Those built on piers rather

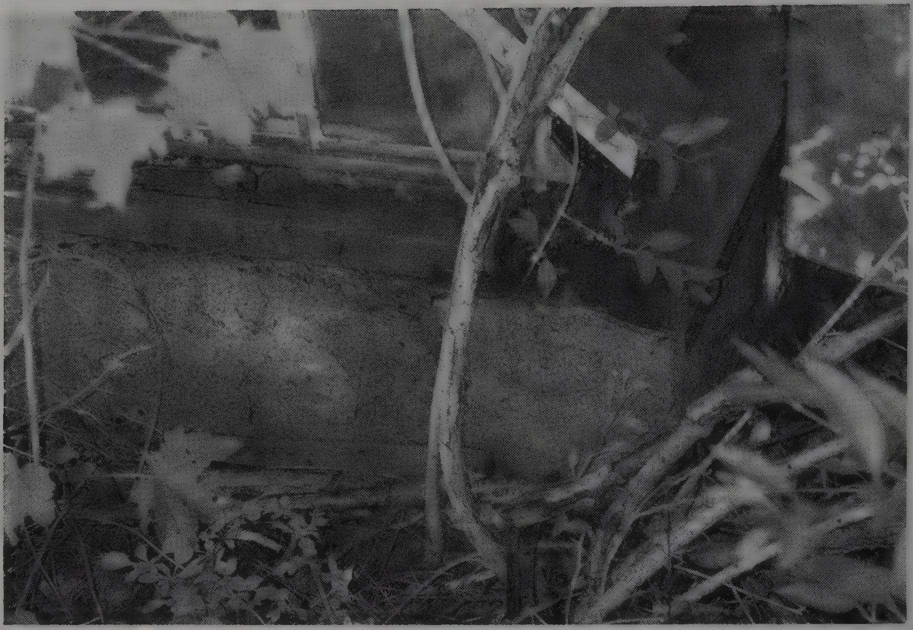


Figure 11. *Detail of the foundation of the Deep River bleach house, 1992, with rough-sheared channel at right, butted against makeshift timber wall plate.* Photograph by the author.

than foundation walls could be shifted about to accommodate new construction or changes in the work routine. Such portability also facilitated the demolition of bleach houses when their sole-use function had ended. Needless to say, plastic keys require no bleaching from the sun. And unlike old factory buildings, low, triangular, all-glass houses make for unsatisfactory warehouses or living quarters. Judging from local commentary and post-use photography, rock-throwing target practice seems to have been their chief attraction in the twilight years before their scrapping.

Foretelling the end of the ivory key, Pratt-Read demolished the great field of bleach houses behind its Deep River factory in the 1940s to clear land for the war effort: building troop-carrying wooden gliders.[26] A handful of bleach houses remained a few miles away in Ivoryton for the diminished key production that resumed after the war.

Who built these structures? The woodwork and bolted angles would not have been beyond the means of the factory shops. But one late-19th-century drawing of proposed bleach houses for Pratt-Read is stamped "Arthur E. Rendle's Horticultural and Glass Roofing Works, 44 & 46 Broadway, New York."[27] The surviving house shows no rolling mill marks on exposed metalwork, but a date around the turn of the century is likely, a period when the ivory factories were expanding their capacity to accommodate the growth in piano manufacturing.[28]

Ownership of the last bleach house rests with Suda's granddaughter who has agreed to donate it to the Deep River Historical Society if means can be found to remove it to the society's grounds a few blocks up Main Street. Meanwhile, the bower provides a dark, protective camouflage for the structure while it once again awaits sunny days.

Key-Making

Prior to their arrival at the bleach house, the ivory key veneers underwent a series of sawings, soakings, examinations, and other manipulations. After their sun-bleaching, the inspections and physical treatments continued before their final attachment to upright and grand pianos. A review of the ivory key manufacturing process, as practiced in the region early in the 20th century, will properly place the bleach house in the sequence of distinct but interconnected events that were taking place on both sides of the glass. Such a review also may foster a greater appreciation for this relic and the high levels of material control achieved by Connecticut ivoryworkers.[29]

Tusk Selection: The buyers in Europe or in Mombasa and Zanzibar examining raw tusks for the piano trade sought the thicker, mature tusks weighing 40 pounds or more (figure 4). They checked for hidden masses of lead poured by traders into the deep pulp cavity to increase scale weights, outward

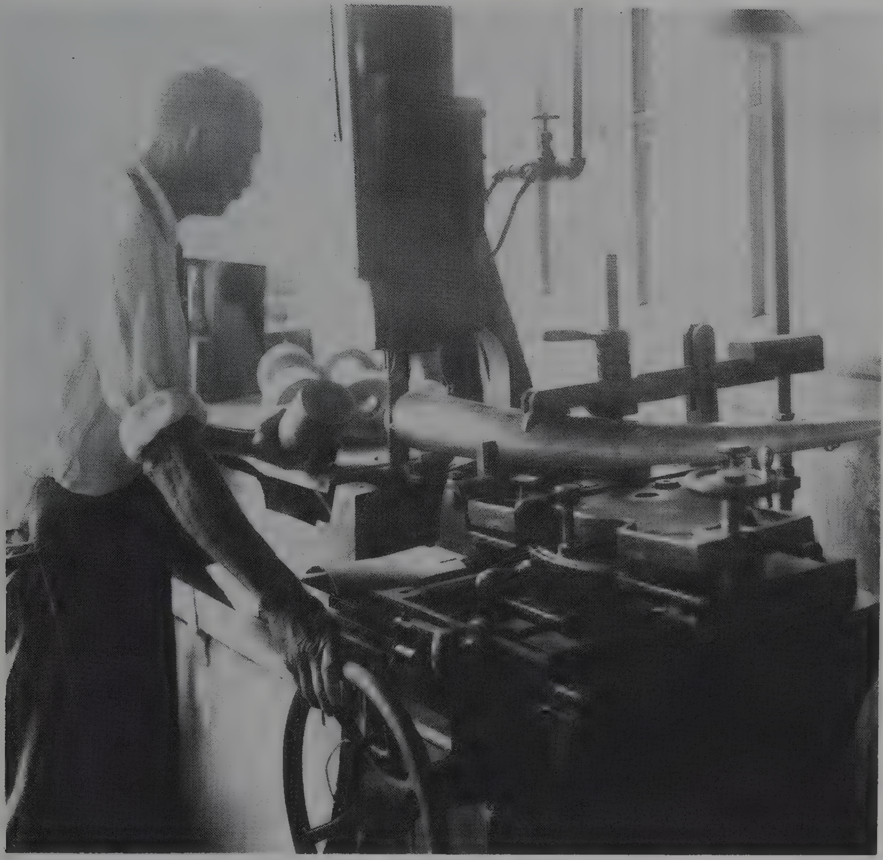


Figure 12. *Junking a tusk into four-inch sections on a shop-modified, water-cooled bandsaw at Pratt-Read, 1920s.* Ernst D. Moore Collection.

signs of internal decay, and evidence of imbedded bullets from old unsuccessful hunts. Tusks were graded on a point system that deducted one or more marks for such defects as spots, streaks, cracks, rings, or wear, all signs of potential problems internally that could diminish the yield of quality keys.

Further grading and weighing would occur at the factories where tusks were bundled in straw and stored in the ivory vaults. If subgrade for piano keys, they might go to the comb shops or other specialty works on the premises or be resold to factories elsewhere in the region.

Junking: Heavy-framed woodworking bandsaws modified with deep, fine-toothed blades, radial indexing, and coolant jets were the first machines to contact the tusk (figure 12). Saw operators "junked" the central portion into four-inch cylindrical blocks sawed at right angles to the tusk. The actual junk—the tip and the furrowed ivory around the pulp cavity—would pass to other production lines for lesser ivory goods or join the ivory sawdust to be burned and ground to a silky powder for use as the paint pigment or decolorizing agent ivory black.[30]

Blocking: Carried to a separate bench under a damp cloth, each block's end-grain would be carefully scribed by a blocker with lines showing the optimal distribution of head and tail sections obtainable inside the ivory's tough husk-like outer layer (figure 8), quite like dimensioned lumber being marked for sectioning from a solid log. All head and tail sections stood upright and faced the center of the tusk to keep the axial grain patterns relatively uniform. Crosscut keys would have been intolerable, both structurally and historically, despite the luminous beauty of ivory's cross-grain.

Parting: In a second saw shop, workers hand-fed the blocks through water-cooled circular parting saws (figure 13) to remove husks and produce the rectangular solids from which the heads and tails would be sawed. The high-quality ivory wedges sawed from between the solids would move elsewhere to become toothpicks, ear cleaners, tool handles, or other ivory wares up to four inches in length.

Slitting: Using stops and guides, key sawyers (figure 14) rapidly fed their head and tail blocks longitudinally through thin, fine-toothed circular saws running in water, working in a back-and-forth "meat-slicing" motion until the blocks were reduced to 1/16th-inch heads or tails on one side and stub residue on the other. The thickness of each head and tail tapered slightly, presenting the thickest portion to the fingered region and producing a thinner, finer joint where head and tail would meet.

Perhaps unintentionally, the circular saw marks on both sides of the keys contributed at a later stage to the uniformity and speed of the bleaching process, exposing greater amounts of angular surface area to the action of the sun. The saw marks also provided a gripping surface for the hot glue during attachment to the keyboard, although toothing machines later augmented this role at Pratt-Read. After this final sawing stage, additional lines of machines profiled each key and undercut the butting edges of each tail and head to ensure a nearly invisible joint.

Chemical Bleaching: Prior to World War I, there was a near-continuous process of fine-tuning liquid bleaching regimens, judging from the diversity of additives to the basic hydrogen peroxide solution described in the surviving records. The slightest excesses in grain and color were grounds for reconsidering and adjusting the makeup of the liquids in which the key veneers soaked prior to their placement in the bleach house.

Keeping sets of ivories sawed from the same tusk (not necessarily from the same block) together, key workers moved the ivory slips through baths of warm water and drying chambers, ultimately loading heads and tails into glass jars filled with dilute hydrogen peroxide spiked with either potash, turpentine, sulfuric acid, kerosene, ether, or distilled water, depending on the decade, the vogue of the factory, or the appearance of the ivories. By the early 20th century, Pratt-Read and the Wood & Brooks Company in Buffalo (figure 15) had settled on a straight hydrogen peroxide bath lasting up to 72 hours. Since 1818, hydrogen peroxide was known as a powerful oxidizing agent, relaxing and liberating heavier molecular compounds within porous materials, an action accelerated by sunlight.

Pre-soak and post-soak ivory-drying schedules and bleach-water temperatures were special areas of concern, given ivory's structural and visual volatility. Operator expertise and suitable facilities were vital in maintaining the level of control these procedures required, as Charles Wood, head of Wood & Brooks, confided to a colleague in 1914: "We have had difficulties for many years with yellow ivory, on account of the fact that we lacked the space to dry the ivory out thoroughly before it was put into the bleach water, with the result that when it was rushed through the least bit on this process we would be up against it later on."[31]

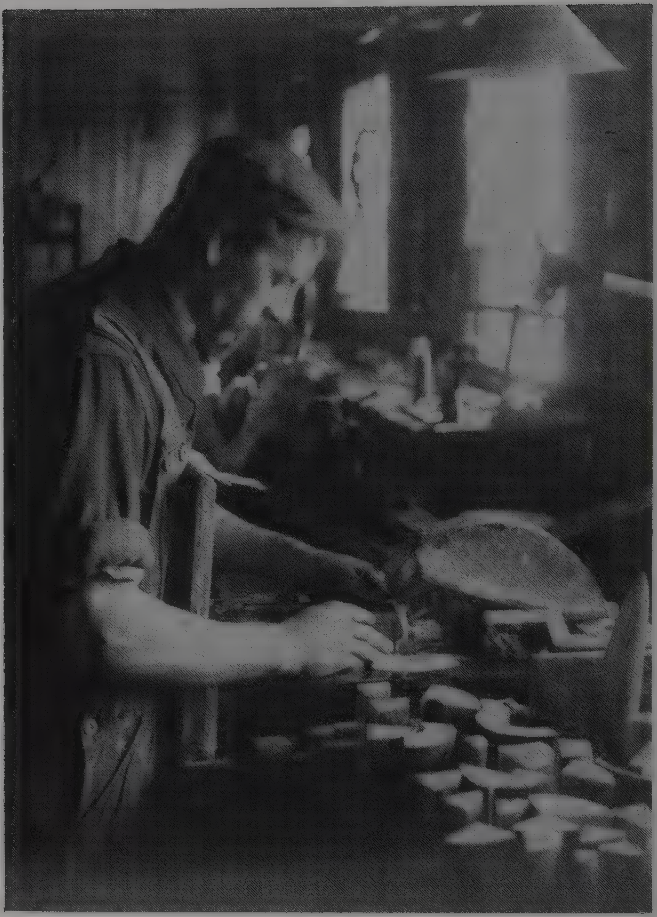


Figure 13. *A sawyer at Wood & Brooks (Buffalo) parting junked tusk sections into head and tail blocks. Semi-sawed blocks stand in the foreground. Note coolant shields over saw blade and sawyer's chest.* Wood & Brooks Records Collection (457), Archives Center, National Museum of American History, Smithsonian Institution.

Workers dumped the saturated ivory into large, screened trays for days of drying as the heads and tails adapted to conditions in the humid, daylit bleach house (figure 16), a period during which the heat inside the glasshouse would further activate the residual bleaching chemicals within the ivory.

Sun-Bleaching: By the 1840s worked ivory systematically was being exposed to the action of the sun's rays in Connecticut while confined behind glass, judging from Ulysses Pratt's bleaching patent of 1852 that briefly reviews existing

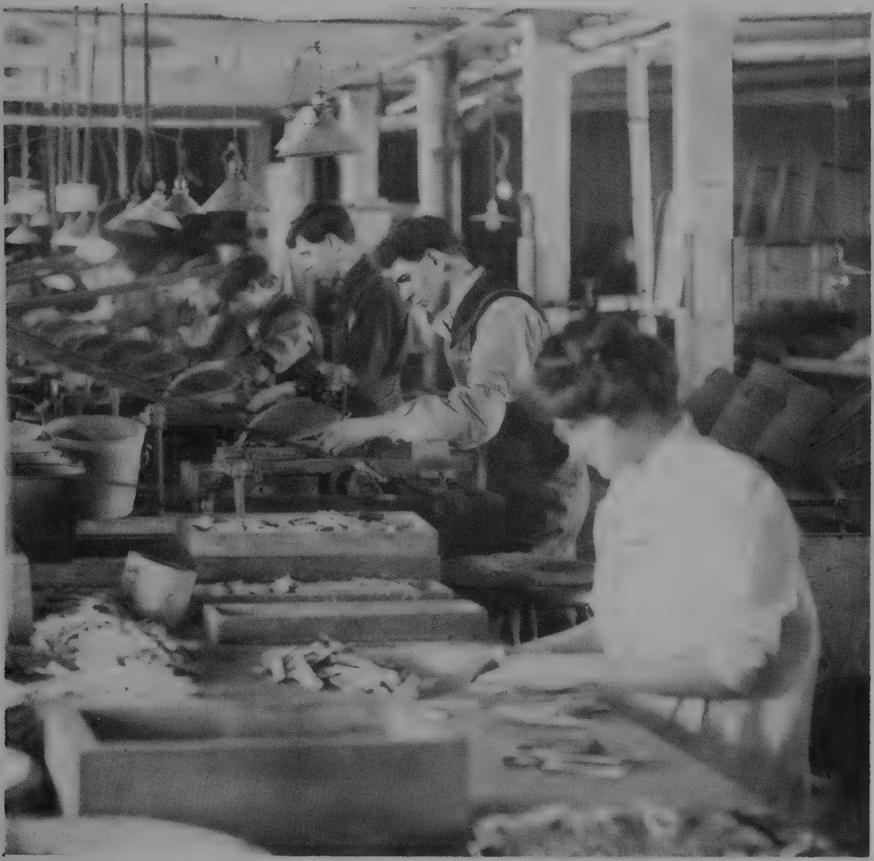


Figure 14. *A slitting line at Wood & Brooks, sawing blocks into ivory key veneers, 1928. Worker in foreground sorts scrap head and tail residue*. Wood & Brooks Collection.

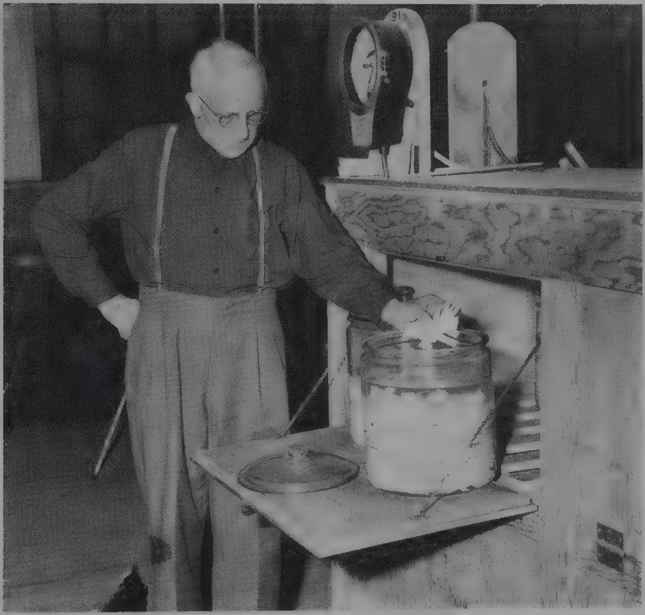


Figure 15. *Wood & Brooks shop foreman Andrew Probst pulls a fistful of heads and tails from a jar of peroxide bleach, 1920s. Note temperature recorder and shrouded bleaching cabinet*. Wood & Brooks Collection.

techniques: "bleaching thin pieces of ivory, for veneering piano keys and other purposes by placing the ivory upon trays, boards and other flat supports . . . and covering the same with glass in frames placed at various angles, and sometimes suspending the ivory by strings and loops or otherwise, in front of a common glass window."[32]

Sun-bleaching continued largely unchanged from this basic approach until ivory's outright displacement in the 1950s. Neither artificial light nor chemical bleaches ever surpassed the effectiveness of sunlight, despite the sun's seasonal randomness and unregulated intensity.

Why the glass? Why not lay the ivory in open-air racks? Beyond protection from the elements, the glass served as a shield to block the sun's ultraviolet lightwaves. These high-energy rays can break down vital chemical bonds within the ivory that maintain its whiteness and structure, and the ivory could burn and peel beneath the unmodulated action of the sun. Such effects had been known theoretically since the 17th century, but Connecticut's first ivory bleachers could have discovered this on their own through trial and error. Finally, the glass furnished an environment in which captive

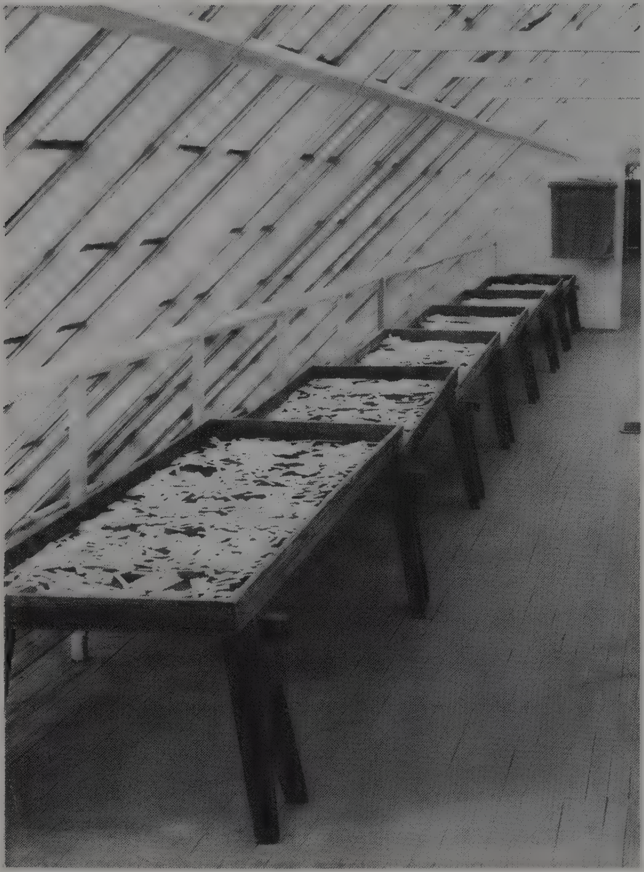


Figure 16. *Inside a Wood & Brooks bleach house, heads and tails drying in trays below the glass prior to racking, 1920s.* Wood & Brooks Collection.

heat and humidity could facilitate the bleaching process, as the sun's infrared and visible lightwaves passed through to act on the pigmented ivory.

While maintaining the tusk integrity of each key set, bleach house workers loaded heads and tails from the drying trays into non-corrosive, zinc-fitted wood racks, inclining each ivory in a stepped fashion similar to the outdoor seating arrangements known today as bleachers. The racks fitted into guides or were pegged into the window frames an inch or so below the glass (figures 17, 18). Sun time varied from weeks to a month or more (figure 19), depending on available light, the season, and the appearance of the ivory. Every head and tail was turned during the bleaching to thoroughly whiten each edge and the interior (thin ivory tends to be translucent). A completed bleach would be gauged visually and/or with a weight test to determine total moisture loss.

More than one inventor attempted to accelerate the sun-bleach by locking the ivory into reversible glass racks, placing reflective materials below the keys, or turning the keys on end (U.S. Patents 15,590, 15,983, and 13,928). But no such approach succeeded in displacing the laborious hand-flipping of each head and tail and the watchfulness necessary to avoid the cracking or warping of keys due to excessive moisture loss.

Matching: Scrutiny of the individual keys intensified with the stacking and movement of the sets to the factory matching tables, after the keys once again had been dumped into trays and allowed to cool and dry further, out of the direct rays of the sun.

Pratt-Read and Wood & Brooks (figure 20) employed women to create the matched keyboard, judging from existing photographs and retired workers' testimony (figure 21). Theirs was essentially a reconstructive task, selecting heads and tails sawed from the same strata or depth of the common tusk, enabling a given key set to exhibit the same fineness or coarseness of grain from one end of the keyboard to the other. The matchers essentially sought to create within a single horizontal plane what had existed vertically and in circular form within the tusk.

In a pioneering body of work, Anthony Cutler has isolated the ways in which the unpredictable directions of elephant ivory's longitudinal grain were exploited by Byzantine ivorycarvers in the third to tenth centuries A.D.[33] The grain takes unexpected twists and loops as it undulates in three dimensions through the tusk. These hidden features added definition and realism to sculptural forms if the grain was properly managed by the carver. In Connecticut, too, grain management was a concern, but for the opposite reason.

The best grades of keys were matched from center-cut ivory that displayed the least figure. (See figure 22.) But the more plentiful and variegated keys from the outer half of the tusk's diameter struck one piano trade publication in 1925 as actually more desirable, momentarily placing in question the linkage of grainlessness with quality: "The highly figured ivory is prefered by makers of fine toilet articles and by piano makers in Europe. It was found by them to have better wearing qualities. . . . The piano makers of the United States, if they choose, with the cooperation of the key makers, can make the figure in an ivory key an asset and not a liability. The result will probably be a slight increase in the price of the figured ivory. . . . Is it not foolish for the piano salesman to point to plain ivory on the keys of his instrument as evidence that the piano is of superior quality?"[34] American keymakers, probably aware that the center-cut ivory was

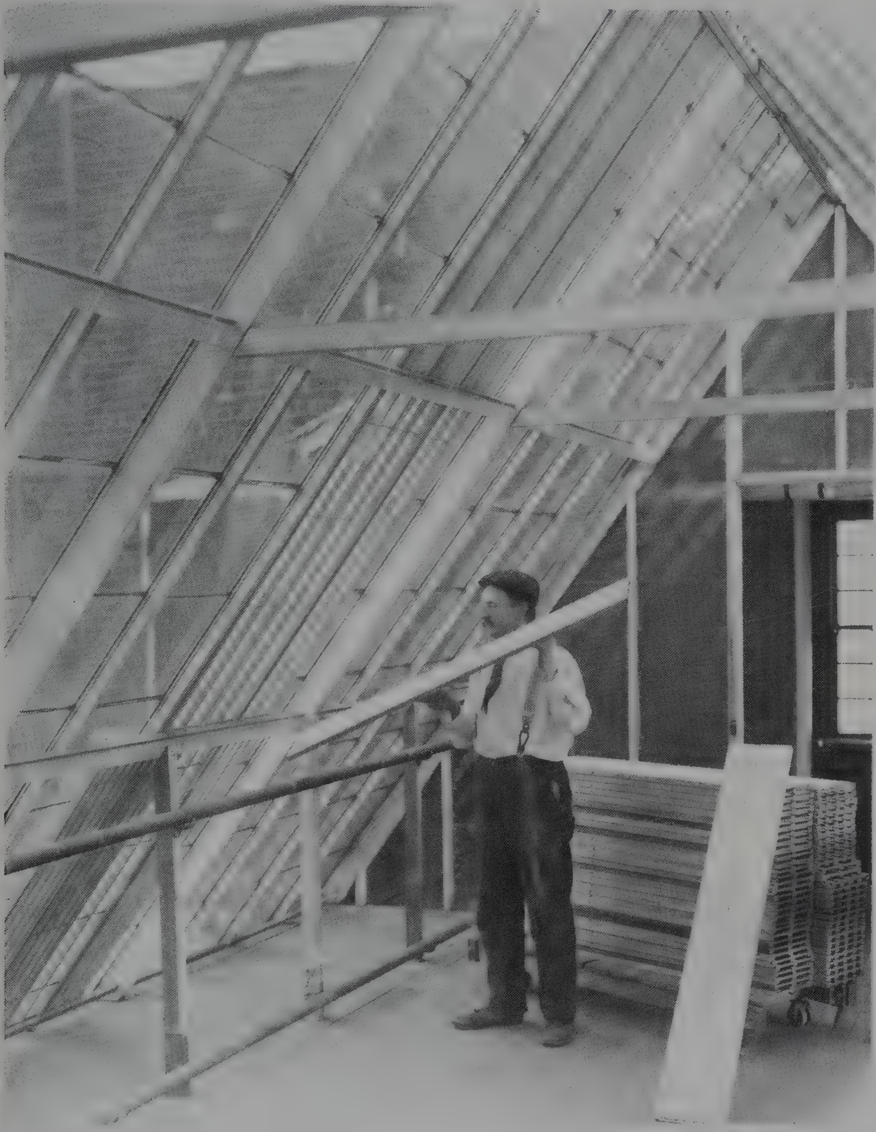


Figure 17. *A rack of tails being "put to glass" at Wood & Brooks's unusually spacious bleach house on the roof of its main factory, 1920s. Note cartful of loaded racks.* Wood & Brooks Collection.

younger and less subject to dryness, cracking, and yellowing, did not share this thinking, retaining their anti-figure preferences to the last days of the ivory key and into the completely grainless white plastics that followed.

Scrutinizing their stacks of ivories for telltale grain patterns, the matchers sat opposite large windows with northern exposure. Natural light was supplemented in later years with ultraviolet lighting hung directly over the tables to reveal more fully subtle grain variations. Completed key sets would be struck with a sloping pencil line that enabled the sequence to be swiftly re-established on the actual keyboard.

Laying: Head and tail sets were reunited in the laying department on sugarpine or basswood keyboards, the keys butted head-to-tail, and across the board head-to-head with no spacing between. A six-inch strip of linen served as a separation and expansion layer between beds of hot glue applied to board and ivories. Once laid, covered with oiled paper, pressed, and set, the keys would undergo one more ivory-surfacing procedure.

Grailing: Removing pencil marks, glue, burrs, paper, and other imperfections, hand-guided grailing machines passed saucer-like surface-milling cutters across the full ivory

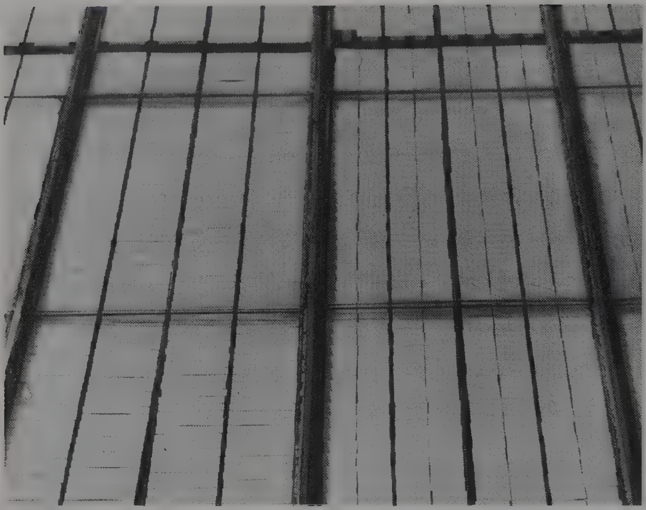
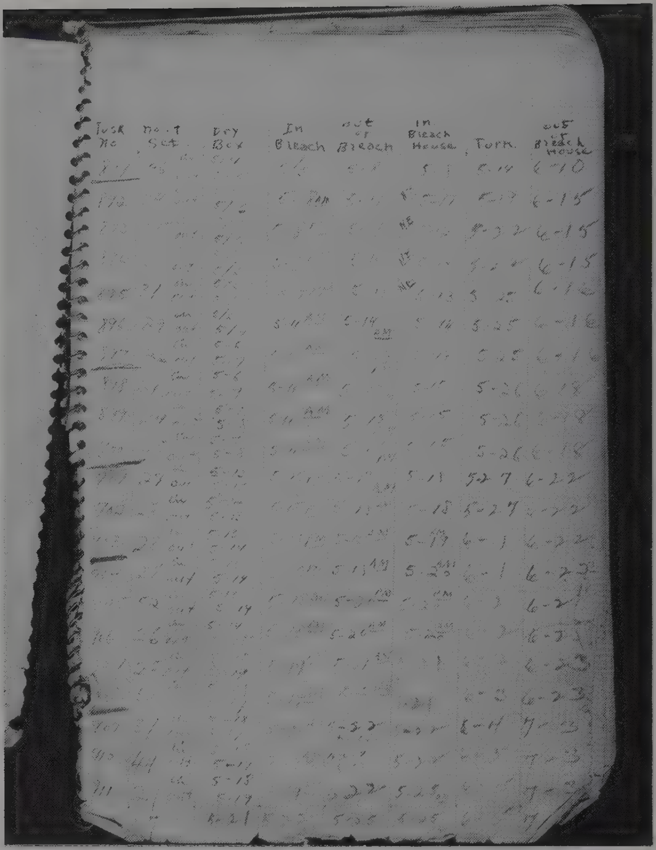


Figure 18. *Bleach house outside window detail, inclined tails and heads resting on zinc-toothed racks, 1930s.* Pratt-Read Records.



Tusk No	No. of Set	Dry Box	In Bleach	out of Bleach	in Bleach House	Turn.	out of Bleach House

Figure 19. *Page of a Pratt-Read bleaching log, 1950s, tracking keys by tusk number and exposure to chemical and sun bleaches. Tusk 905 yielded 52 sets of keys requiring 37 days of bleaching.* Pratt-Read Records.

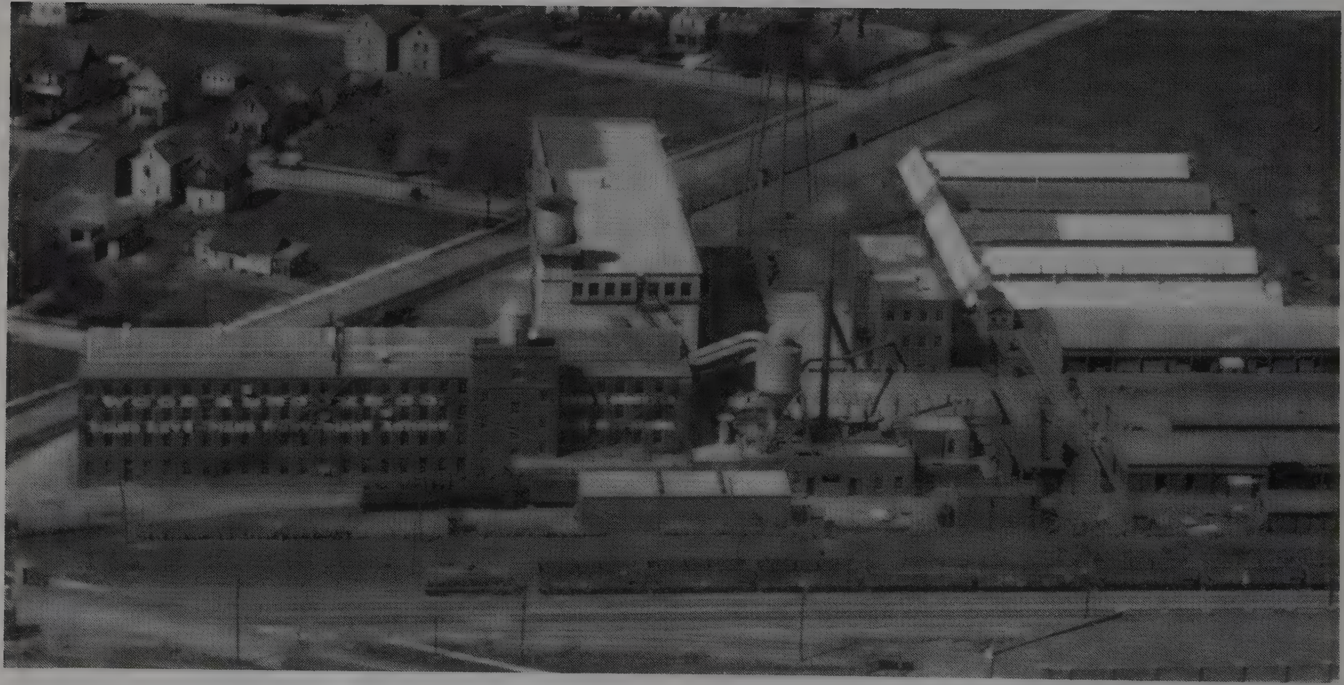


Figure 20. *Aerial view of the Wood & Brooks factory, Buffalo, 1930s. Bleach house on the roof of the main building appears in figure 17. Other bleach houses sit Connecticut-style on the ground (right). All buildings except bleach houses remain standing today.* Wood & Brooks Collection.

keyboard, producing a uniform surface and precise key height. Felt buffing wheels polished the keys, removing the grail's circular tool marks and giving the keys a soft, reflective finish before their final segmentation into separate ivory-wood keys.

Keyboard Sawing: The wood panel below the ivories adopted the profiles of the individual heads when the full board was hand-fed into five-bladed circular gang saws to part the three-ply ivory-linen-wood sandwich (figure 23). This pass produced the final head and key width. Other band and circular saws completed the segmenting of keys from the rear of the board and prepared slots for the addition of the ebony sharps, fabricated in an adjacent shop. Following the corner-beveling of each head, the journey ended with attachment to action assemblies and insertion into the piano case.

All of the ivory's wetting, drying, heating, and cooling represents a remarkable odyssey, given ivory's storied readiness to crack and twist when exposed to sudden shifts in moisture content and ambient temperature. The hot glues, the immersions in bleaching solutions, the passage through water-cooled saws, the action of the sun, and the other invasive treatments added up to a punishing regimen for any natural material, certainly one as reactionary as ivory.

Yet the open defiance of this reputation for delicacy suggests the facility with which the keymakers understood ivory's real limitations and abilities, mocking those imposed by non-ivoryworkers through latter-day examinations of long-finished ivory goods.[35]

Preservation

After World War II a pair of trends led to the current circumstance of a solitary rusted bleach house sitting nearly glassless in a tangle of Deep River vegetation (figure 24). Neither trend alone would have had quite the success that the two did in concert.

By 1949 managers at Pratt-Read were expressing frustration over the lack of young ivoryworkers on hand to renew the skills required to meet a swelling postwar demand for pianos: "A skilled worker is needed; one who can lay both ivory and celluloid, sand, scrape and polish, and yet there seems to be no one to draw on. At present time we have only two regular ivory layers with no younger person breaking in. The average age of our ivory workers from the saw room, bleaching, matching, laying, and processing, probably is over sixty. Let us do something about this situation before our skills are lost completely. There is something wrong with our system."[36]

Within a few years, industrial chemists transformed this warning into prophecy. Plastic was looked on by Pratt-Read executives not only as a cheaper key material more accessible than ivory. Peter Comstock, company president, stated the reasoning in his 1956 annual report: "New types of plastic key covers . . . will gradually simplify our production problems as the processing of ivory key veneers from elephant tusks is a difficult, expensive and time-consuming task."[37]

Synthetic injection-molded naturals and sharps eliminated

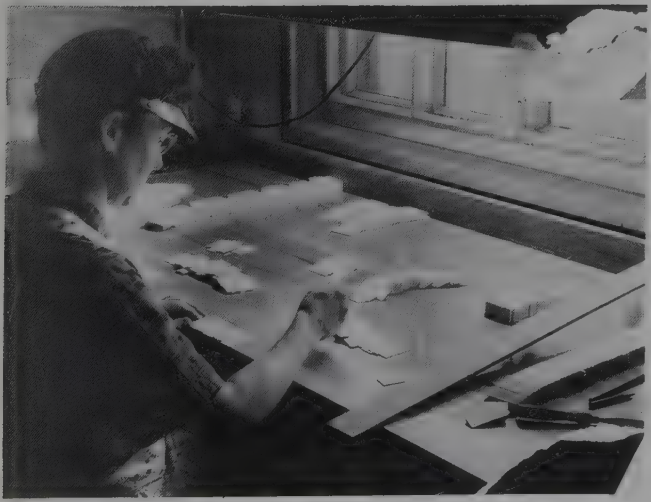


Figure 21. *Evelyn Berry matching key heads at Wood & Brooks, 1930s, assisted by northern daylight, ultraviolet tube, and eyeshade.* Wood & Brooks Collection.

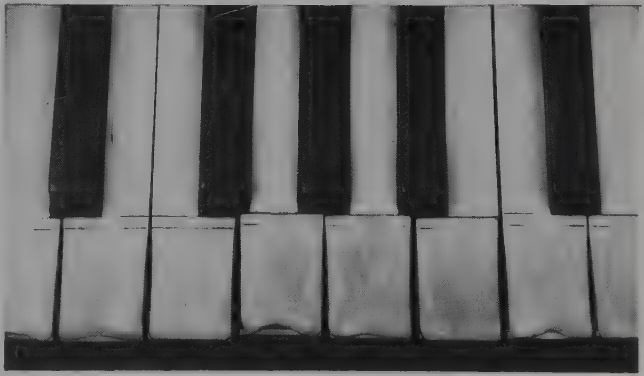


Figure 22. *Highly figured heads age-darkened and worn with usage on a 17th-century Italian harpsichord. The visible V-grain patterns (pointing toward the tip of the tusk) show these keys to have come from the prime ivory around the tusk's central axis. Imperfect matching reversed the direction of some keys.* Photo by Doc Dougherty, 1993; Division of Musical History, National Museum of American History, Smithsonian Institution.

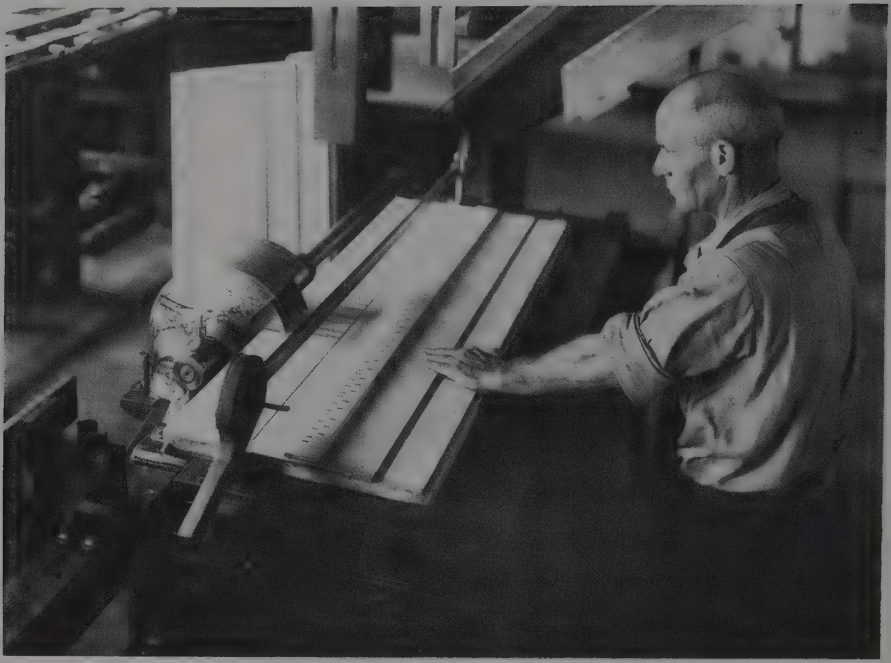


Figure 23. *Parting the heads of a grailed keyboard with a five-bladed circular saw at Pratt-Read, 1920s.* Ernst D. Moore Collection.

the host of hand trades that vested exclusive production knowledge in the increasingly frail hands of the ivory and ebony workers. Pratt-Read's commitment to the new laboratory-based technology was reinforced in 1961 by its acquisition of Tech-Art Plastics Company of Morristown, New Jersey, specializing in plastic piano components.[38] Television's inroads into the American piano market also pressed the industry to cut costs and diversify output. In 25 years, Pratt-Read, having become a fabricator of plastic and wood components for manufacturers of furniture and hardware, would be out of the piano business altogether.

By 1958 ivory no longer was cut into piano keys in Connecticut. Buffalo's Wood & Brooks closed its doors in 1970. Any new American-built pianos subsequently fitted with ivory carried foreign veneer sets or full keyboards from abroad. But this too was a time-bound adjustment, dependent on the continued availability of the raw material.

At the other end of the equation, elephant herds in Africa had been disappearing from coastal regions since the late 19th century. The smaller Asian species was also in retreat in India and Southeast Asia. By World War I, billiard balls had joined with piano keys, knife handles, and finally tourist carvings mass-produced in Asia to place formidable pressure on ivory suppliers, and in turn on elephants.

Competitive demands for massive amounts of the raw material did not encourage the protection or even intelligent management of the all-important but exceedingly remote source—mature elephants with large tusks. The optimal solution—salvaging fully grown tusks only from old elephants that had died of natural causes—apparently was not a realistic market option. Virtually unregulated hunting continued until surveys in the 1970s revealed astounding reductions in elephant populations across Africa and Asia.[39] Unlike the Asian species, African elephants also have been threatened with extinction by their reluctance to breed in captivity.

Subsequent U.S. government restrictions and in 1989 the domestic ivory import-export ban (the African Elephant Conservation Act) rendered the ivory piano key politically obsolete, but it had become industrially obsolete three decades earlier. Abroad, the United Nations Convention on International Trade in Endangered Species has placed severe restrictions on the movement of raw or worked ivory from nations with herds of wild elephants and walrus to the ivory-importing nations, chiefly in Europe, North America, and Asia.[40]

Another equally global dilemma has focused on the concert pianist's unsentimental regard for the ivory key. Musicians who perspire heavily have discovered an embarrassing tendency for their fingers to hydroplane across the slick surfaces of mirror-finish plastic keys, a problem once resolved by insisting that concert grand pianos be fitted with ivory.[41] Pratt-Read and many other firms have introduced various celluloids and acrylics under names such as Ivorine, Ivo-

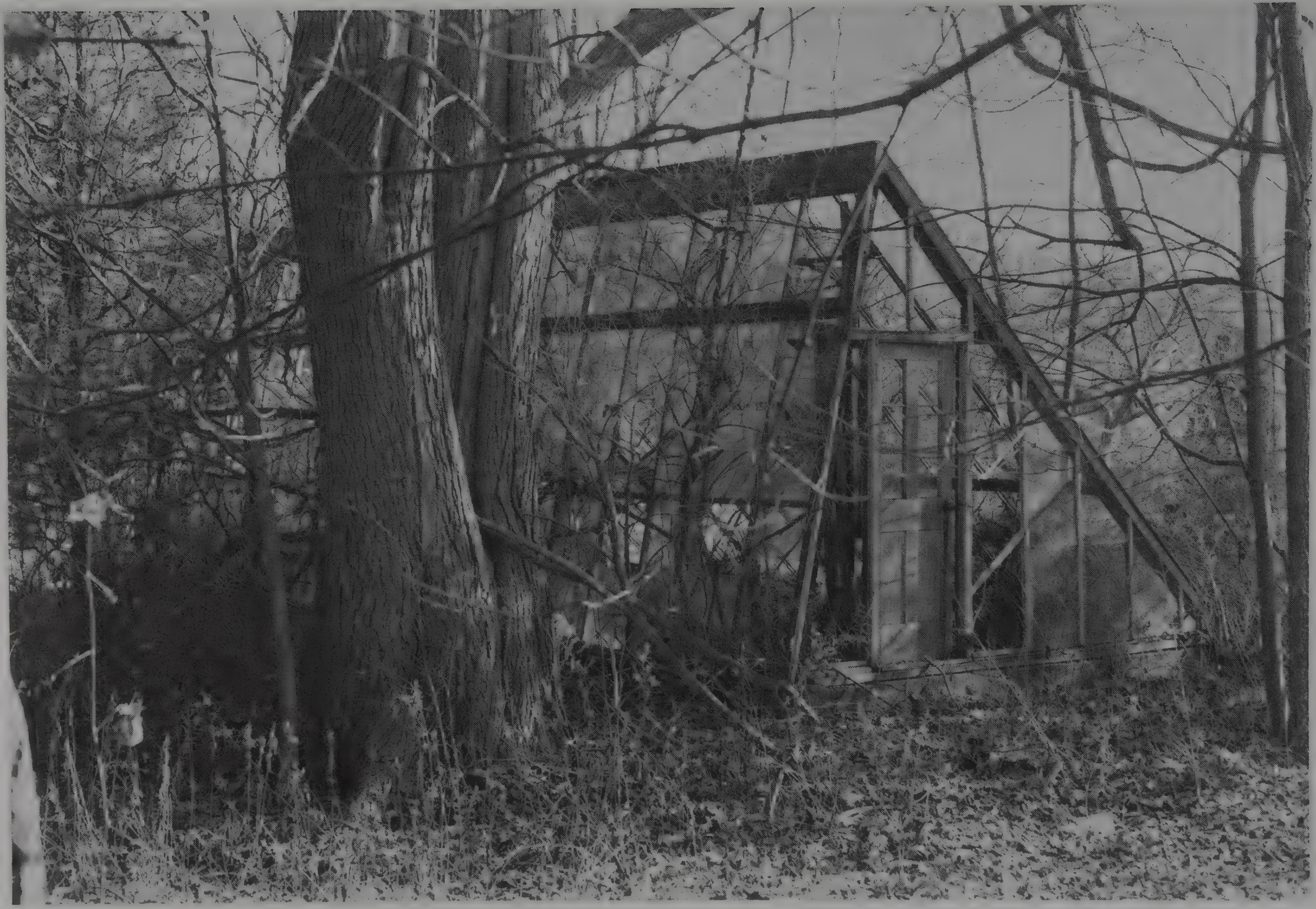


Figure 24. *Rear view of the Deep River bleach house, showing severed end panel, 1988. Last of species.* Photograph by the author.

plast, and Ivorite to replicate ivory's whiteness. But the peculiar grip of the ivory keyboard, a concern primarily of professional players, has been more elusive, despite trial uses of cow bone, mammoth and fossil-walrus ivory, and textured plastic. A product developed in 1992 by a tribologist (friction engineer) at Rensselaer Polytechnic Institute in Troy, New York, with support from Steinway & Sons, may open a new chapter in this quest.

The new substance, trade-named RPIvory, replicates the look, the feel, and—according to a number of pianists—the performance of the elephant ivory key.[42] Investigations with a scanning electron microscope at RPI revealed ivory's very irregular and porous microsurface. Even highly finished ivory was discovered to have a rough terrain of random, non-parallel ridges and valleys, pockmarked with a myriad of pores. RPIvory is cast from powdered polymers using an assortment of ivory keys as patterns that reproduce this essential surface randomness and porosity. Such methods, a direct consequence of ivory's new outlawed status, at last may satisfy one of the most dedicated groups of ivory users—the pianists—while leaving to an earlier era the costly methods of ivory's acquisition and meticulous processing.

Conclusion

As the citizens of Deep River debate the worth of preserving the bleach house on the grounds behind their stone-walled museum, let them remember not just the elephants and the pianos, but the matchers, grailers, junkers, blockers, and sawyers—almost all gone now—who displayed levels of skill and craft mastery that are exceedingly worthy of commemoration today. With or without glass, the bleach house becomes a two-way window, looking in on the complex community industry that transformed a unique material, and out on the world that transformed the industry's distant animal source and the musical end product.

Beyond these reasons is the simple fact that this piano key bleach house is the only one left. Elephants are not alone in their stand against extinction.

Acknowledgments

For their help with this study, considerable thanks go to Edith DeForest, Al Gielow, Edith Sibley, Frank Stopa, George Schmelzer, Craig Orr, and the late Reginald Comstock.

Notes

1. Edgard O. Espinoza and Mary-Jacque Mann, *Identification Guide for Ivory and Ivory Substitutes* (Washington, D.C.: World Wildlife Fund, 1991); and T. K. Penniman, *Pictures of Ivory and Other Animal Teeth Bone and Antler* (Oxford: Oxford University Press, 1952).
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3. Norman E. Flayderman, *Scrimshaw and Scrimshanders: Whales and Whalemen* (New Milford, Conn.: N. Flayderman and Co., 1972), p. 29; and William W. Fitzhugh and Aron Crowell, eds., *Crossroads of Continents: Cultures of Siberia and Alaska* (Washington, D.C.: Smithsonian Institution Press, 1988), figs. 105, 327.
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10. *The New Grove Dictionary of Musical Instruments,* vol. 2 (1984), "keyboard," p. 383.
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12. Quoted in *Dwight's Journal* (January 28, 1854):133.
13. See U.S. Patents 8,639, 13,928, 15,590, and 15,983 for improvements in bleaching apparatus.
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24. Field measurements recorded August 1992 by author. Head and tail racks from Pratt-Read examined by author in Division of Musical History, National Museum of American History, Smithsonian Institution.
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27. Bleach house orthographic drawings in Pratt-Read Corporation Records.
28. William A. Worcester, "Musical Instruments, Attachments, and Materials," in *Census of Manufactures for 1905*, pt. 4 (Washington, D.C.: Government Printing Office, 1908), pp. 239–251.
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35. Raymond H. LaFontaine and Patricia A. Wood, "The Stabilization of Ivory against Relative Humidity Fluctuations," *Studies in Conservation* 27 (1982):109–117.
36. George C. Seeley to R. P. Wright, November 29, 1949, Pratt-Read Corporation Records.
37. Comstock quoted in Johnson (n. 5 above), p. 100.
38. Pratt-Read directors' minute books reveal a gradual 1950s' scaling down from ivory and concurrent shift to outside suppliers of premolded plastic key covers. Pratt-Read Corporation Records.
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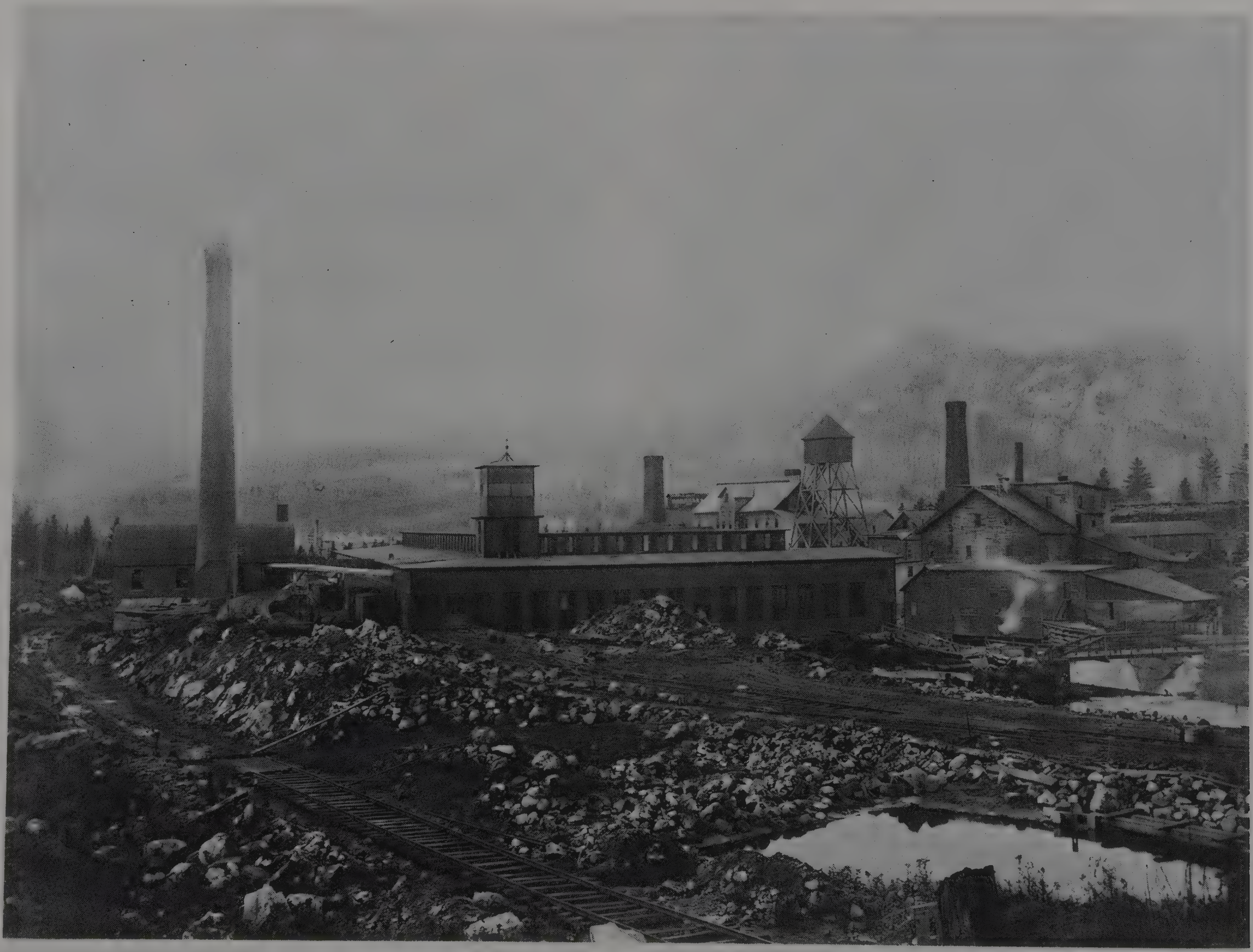

Figure 1. *(A 1286) Riverside Mill constructed c1890. Photograph copied from an old print. Compare size of this early mill to those of the Burgess Mill in other pictures. The Riverside Mill was one of the earliest paper mills in Berlin.* All photos courtesy of the Brown Company Collection, Institute for New Hampshire Studies, Plymouth State College.

Photo Essay
Documenting the History of an Industrial City: The Brown Company Photograph Collection of Berlin, New Hampshire

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William L. Taylor

Nestled in the valley of the Androscoggin River just north of the highest peaks of the White Mountains lies the industrial city of Berlin, New Hampshire. Like so many communities in northern New England, Berlin began as an agricultural settlement in 1824 (originally called Maynesborough),[1] but the arrival of the Atlantic & St. Lawrence Railroad in 1852 (it was leased by the Grand Trunk Railway in 1853) dramatically changed the course of Berlin's history by providing the opportunity to develop the enormous waterpower along the river. The railroad ended the isolation of the region and the difficulties of transporting goods to and from the area, and it permitted the exploitation of the huge timber resources in the Androscoggin Valley.

The river, the outlet for the Rangeley Lakes in Maine, dropped some 100 feet at Berlin, and each foot furnished a potential of 150 horsepower—15,000 horsepower in all.[2] To develop this potential, however, would require more than just a few small dams and impoundments along the river. Harnessing such power required the sizeable capital investment and engineering skills that only large investors could furnish. As a result, Berlin's industrial development occurred only as the investment and skills materialized in the second half of the 19th century.

The Berlin Mills Company organized in 1866 and purchased the H. Winslow & Company sawmill and other properties in Berlin, including two gang saws, three single saws, and one circular saw. Two years later William W. Brown and his brother Lewis T. Brown began purchasing all the assets of the Berlin Mills Company and initiated the transformation of a modest sawmill operation into a major producer of dimension lumber and associated products. It also marked the start of the long association between the Brown family and Berlin.[3]

By the mid-1890s Berlin Mills Company was a huge complex with the most modern technology and equipment. It had six band saws, two shingle machines, two clapboard machines, and two lathe machines. Daily production sometimes reached 180,000 board feet of dimension lumber, which was marketed in the United States and exported to South America, England, and Scotland. A train to Portland, Maine, left the company yards daily with as many as 30 cars of lumber. The company owned about 300,000 acres of forestlands in Maine and New Hampshire on which their woods crews cut annually about 60 million board feet of spruce and pine that was driven down the Androscoggin River to the mills in Berlin. At the turn of the century the Berlin Mills Company had become the largest lumber mill in New England, employing over 600 at the mills and yards in Berlin, 1,200 in the woods operations in winter, and 450 river drivers during the spring log drives.[4]

In 1878 a new forest product industry began operations in Berlin with the construction of a pulp mill owned by the Forest Fibre Company. The company produced soda pulp, a process superseded by the sulphite process in the 1890s. During the 1880s and 1890s the Berlin Mills Company and the Glenn Manufacturing Company also constructed pulp and paper mills. These new facilities completed the transformation of Berlin to a major manufacturer of pulp and paper as well as a major producer of dimension lumber and related products. In 1898, the Glenn Manufacturing Company became part of the newly formed International Paper Company.[5]

So rapid was Berlin's growth that it became a city in 1897. During the first two decades of the 20th century growth continued, and Berlin considered itself a "boom city"[6] increasingly dependent on the prosperity of its major employers, the Berlin Mills Company and International Paper. The expansion of these and other employers attracted enough workers to push the population of the city to 14,000 by 1913. It reached its maximum on the eve of the Great Depression in 1930 with 20,000 inhabitants. Thereafter, a gradual decline began which continues to the present.[7] The International Paper Company mill closed in the early 1930s and there was a gradual reduction in the number of woods and mill jobs at Brown Company and its successor owners. Today Berlin's population is slightly more than 11,000.

The industrial growth of the city brought job seekers from many parts of the United States and Europe. Berlin had a variety of ethnic communities, including Irish, French-Canadian, Swedish, Norwegian, and Ukrainian. These residents gave a special flavor to the city and made Berlin a mecca for winter sports such as hockey and skiing, and renowned for its winter carnivals and ski jumping.

Working standards in Berlin mirrored those of other American industrial communities. Hours were usually long (night shifts were 13 hours and day shifts 11 hours)[8] and working conditions less than ideal. Such circumstances led to successful unionization efforts in Berlin which resulted in a labor and political climate much different from most of the rest of New Hampshire. In 1902 a Union-Labor Party was organized and ran candidates in the city election. During 1906 a group of workers organized a local of the Socialist Party. Labor Day was first celebrated in Berlin in 1902 with a parade that became an annual event. Berlin Socialists regularly ran candidates in city elections and invited Eugene Debs to speak during the 1912 presidential election. The several brotherhood unions also fought for significant improvements in working conditions so that by 1907 the eight hour day had become the standard in the pulp, paper, and lumber mills—a major achievement at this early date.[9]

During the 1930s Berlin had an active Farmer-Labor Party that succeeded in winning the mayoralty race several times. It ousted the traditional power structure centered around the mill managers and leading citizens of the city. Throughout the 20th century strikes have been a common feature of management-labor relations in Berlin. Union efforts and periodic strikes have had the effect of establishing pay rates for paper mill workers that are among the highest of any industrial jobs in northern New England. In the 1990s Berlin remains a strong union city with the United Paperworkers International (AFL-CIO) representing the paper workers employed by James River Corporation.[10]

The Great Depression had a devastating impact on Berlin. International Paper closed its Berlin facility in the early 1930s and the Brown Company (the name change occurred in 1917 because Berlin Mills Company created a negative image for the firm during World War I) entered receivership in 1935. Its plan of reorganization received approval from the U.S. District Court in Portland, Maine, in December 1941. Bankruptcy ended Brown family control of the company; all that would remain was the name.[11] Brown Company prospered during and after World War II but lost its independence in 1968 when Gulf and Western Industries, Inc., purchased control, and it became part of a large conglomerate. Gulf and Western would make many changes, including drastically reducing the activities of the excellent Research Department of the company. In December 1980 the Brown Company name disappeared when the James River Corporation of Richmond, Virginia, purchased the Brown Company through a stock transaction. James River continues to operate the mills and has modernized many of the old Brown Company facilities.[12]

The Brown Company was a very innovative corporation whose Research Department developed many new products and was a leader in paper industry research. Not only did it have an excellent laboratory and staff, but it also documented much of its history by hiring its own photographer. The result was a collection of thousands of photographs of all aspects of the company's operations, including its employees, mills, woods and river operations, the Brown family, and the promotion of products. These photographs also document activities in and around the city of Berlin. A series of movies on company operations and topics relating to conservation and safety furnish insight into corporate attitudes in the 1940s. The individual most identified with these activities is Victor F. Beaudoin, who served as the company's chief photographer for 33 years—from the late 1920s into the 1960s.

Victor Beaudoin created a remarkable photographic archive of the Brown Company and its activities. Using a Graflex large-format camera, he took pictures inside the mills, documented mill construction, traveled to photograph life in the lumber camps, and supervised the making of films. Many of his photographs appeared in Brown Company's newsletter, *The Brown Bulletin,* and were also sent out as publicity of the company's activities. The collection exceeds 12,000 images and is an outstanding record of the company and the community. It is likely one of the best surviving collections of industrial and community activity in the United States.[13]

These photographic archives no longer reside at the old research building of James River Corporation. During the 1980s the still photographs were transferred to the Institute for New Hampshire Studies at Plymouth State College where they are being catalogued and are available for use by researchers. The motion pictures and outtakes now reside at Northeast Historic Film in Bucksport, Maine.

What follows is a sampling of a collection that runs from c1920 to the mid-1960s when management phased out the Research Department. The quality and composition of the pictures suggest the expertise of Victor Beaudoin and his staff and their desire to portray the company in a positive way. It is an outstanding portrayal of industrial and technological history as well as social and economic history.

Notes

1. Bailey K. Davis, *Traditions and Recollections of Berlin* (Berlin, N.H.: Smith-Poley Press, 1990, reprint of 1897 ed.), pp. 8–9.
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3. Davis (n. 1 above), pp. 76, 80.
4. Ibid., pp. 81–83; *Illustrated Industrial Berlin.*
5. *Illustrated Industrial Berlin; Berlin Souvenir: Berlin, Past and Present* (Berlin, N.H.: 1903), p. 30.
6. *Berlin Souvenir*, p. 1.
7. *Illustrated Industrial Berlin;* E. John B. Allen, comp., *Reflections of Berlin* (Berlin, N.H.: Berlin City Bank, n.d.), p. 5.
8. John McCarthy, *Rewind: A History of the Labor Movement in Berlin, New Hampshire* (Berlin, N.H.: The Committee for the Preservation of Berlin's Labor History, 1984) (pamphlet not paginated).
9. Ibid.
10. Ibid.
11. Allen (n. 7 above), pp. 2–3.
12. Ibid., p. 3.
13. See ibid., pp. 49–59. Robert M. Vogel, former curator at the National Museum of American History, stated in a letter to the author in 1983 that "at best there cannot be more than some number on the order of 50 such collections [in the United States]." Robert M. Vogel to William L. Taylor, October 26, 1983, in possession of the author.

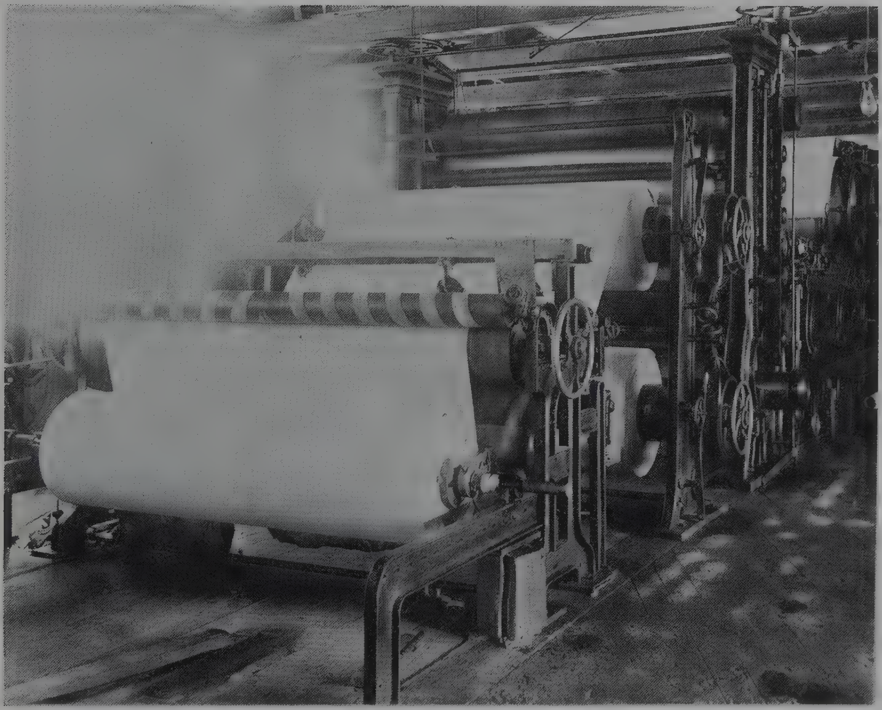


Figure 2. *(A 1279) Riverside Mill rewinding and paper machine, date unknown. Photograph made in 1921 from an earlier print. Note the size of this machine compared to the towel machine installed in the Cascade Mill (figure 15) in 1943. Electric light bulb at extreme right indicates that electricity was installed quite early in the mill.*

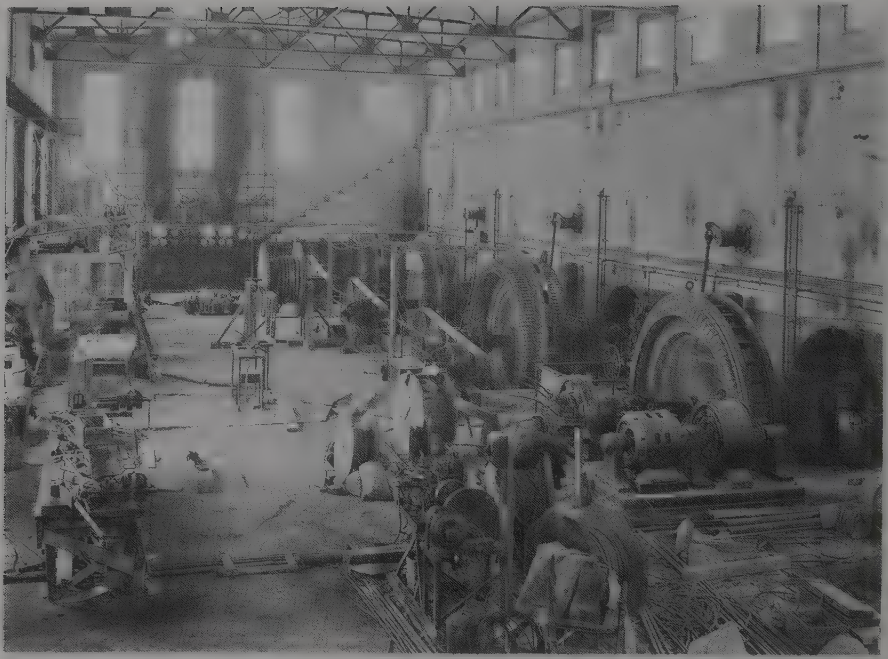


Figure 3. *(A 2502) Interior view of Cross Power Station at Cascade Mill in March 1925. This was one of several electric-generating stations in the Brown Company complex.*

Figure 4. *(A 1166) The Brown Company collection has many examples of construction work in progress. As the next three photographs show, in 1920 and 1921 the company was building penstocks for its new power plant along the Androscoggin River. In this November 1920 view to the north, the crib work and cradle are in place. It shows the construction techniques of the era including the wooden derricks in the right background and the use of a temporary railroad to move materials for the project. The Androscoggin River is on the right of the picture.*

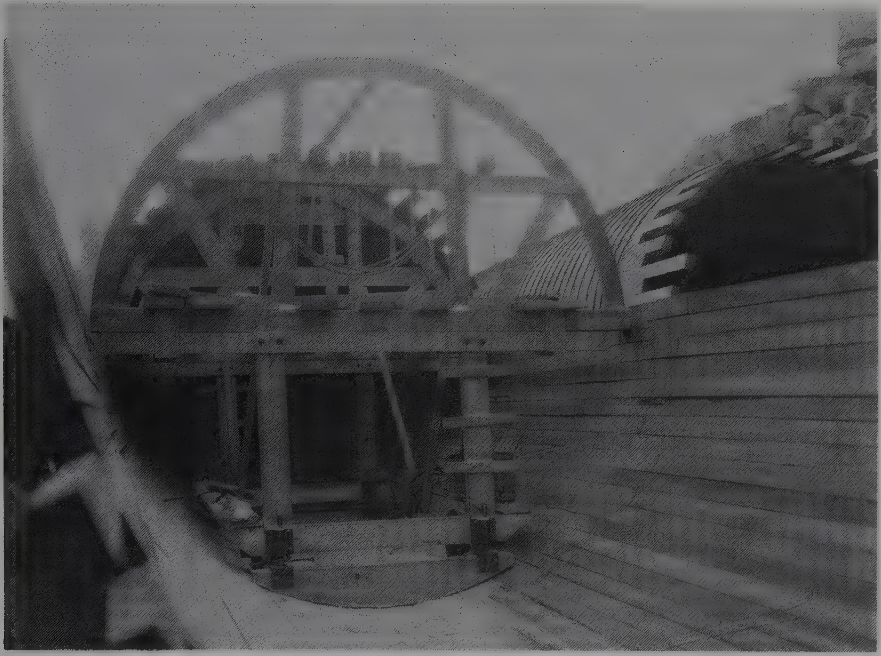
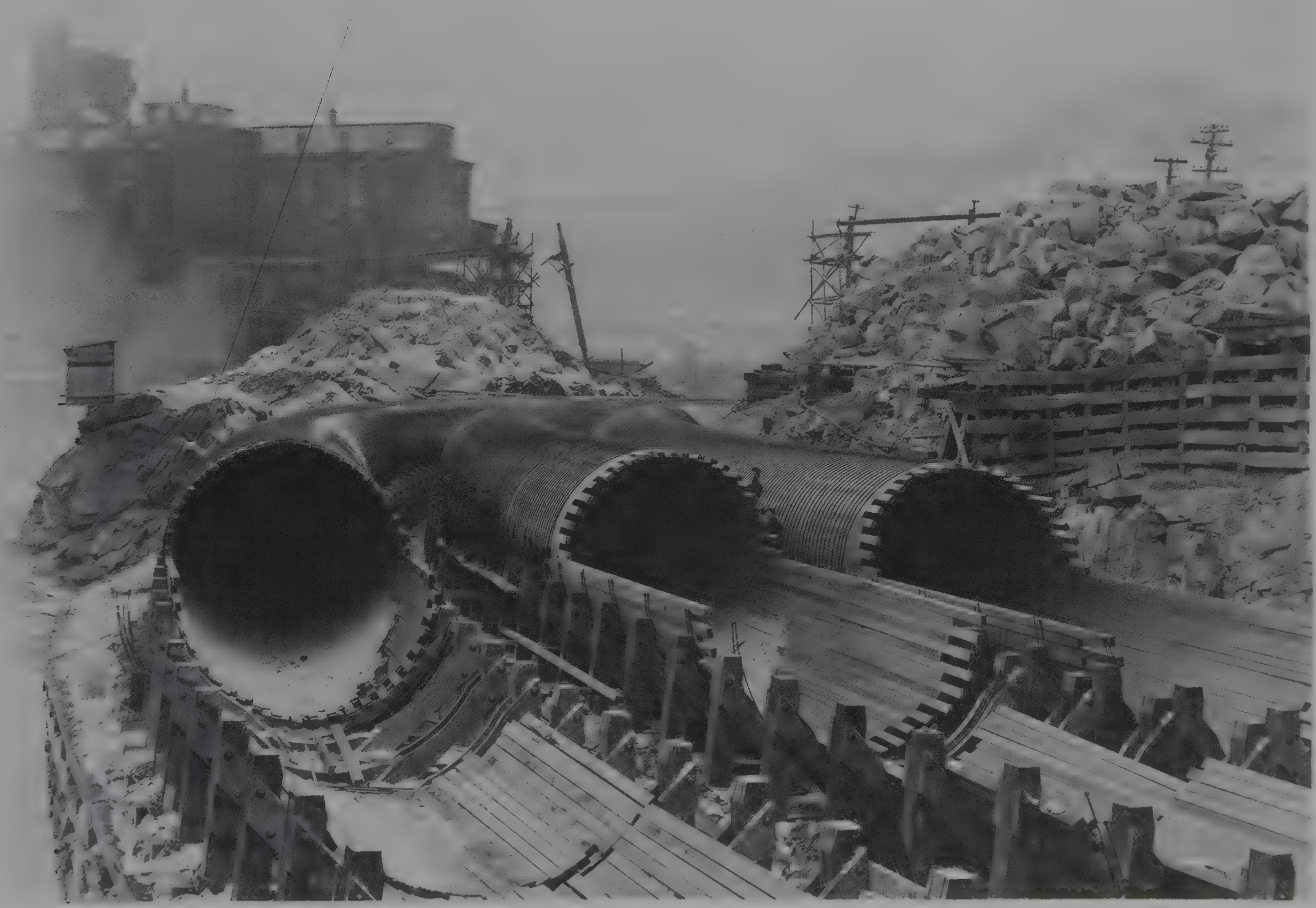


Figure 5. *(A 1351) Detail of penstock construction by Continental Pipe Company in February 1921.*

Figure 6. *(A 1349) View of the north ends of penstocks for new power plant in February 1921. The size and number of penstocks indicate the massive amount of waterpower available from the Androscoggin River in Berlin. Mill in upper left is the company's Burgess Sulphite Mill. Workers in center appear to be placing the iron rods around the penstock to hold it together. Pile of rubble stone at the right rear suggests the amount of blasting necessary to remove the ledge for the penstocks.*



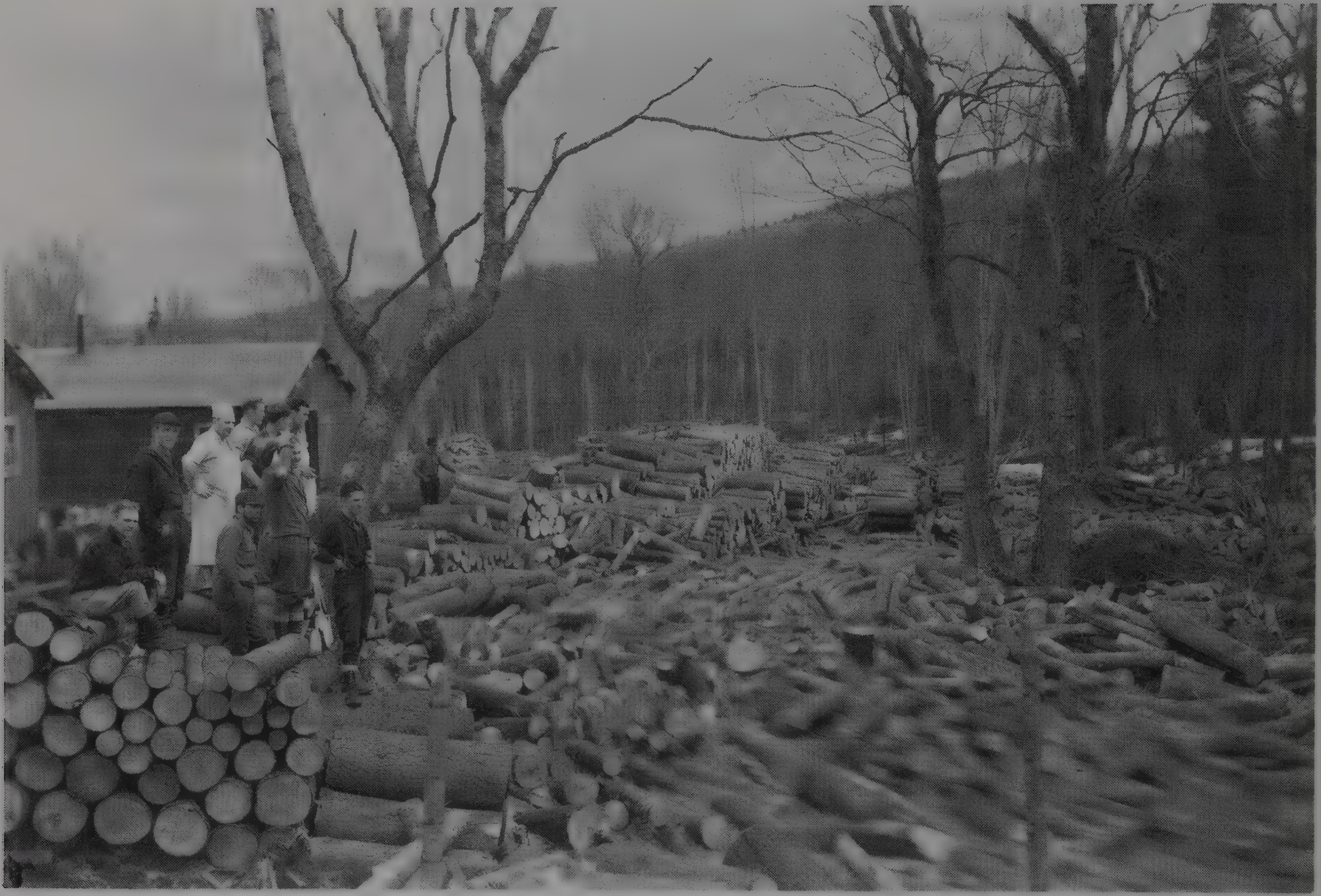


Figure 7. *(BM 667e) Brown Company was a vertically integrated company that controlled vast tracts of timberlands and used much of its own raw material to make various paper products. This April 1938 view of Camp 25 on the South Valley Brook in the Swift Diamond River watershed indicates the beginnings of the process. A crew in the camp are watching pulp logs move along in the brook (blurred area in right front) as they commence their journey toward Berlin where they will be used for pulp and paper. River driving in New England always began during the spring to take advantage of the high water from the melting snow.*

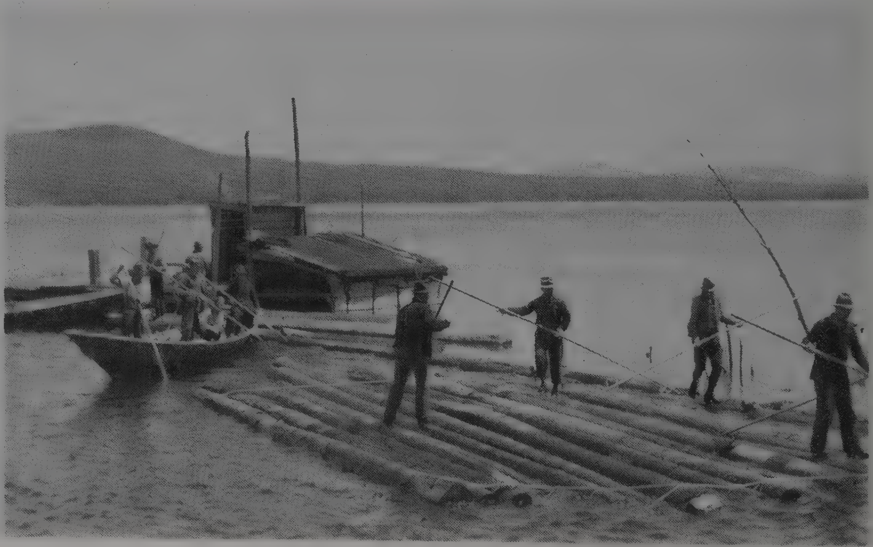


Figure 8. *(BM 680G) The company cut and transported much of its wood from the Rangeley Lakes region of Maine. Here is a view of the spring drive in May 1938 as the boat crew is working on a boom (a group of logs chained together and used to transport pulp logs across lakes) in Lake Umbagog, the westernmost of the Rangeley Lakes. Note the bateaux at left center. Such vessels were employed extensively by river drivers in northern New England.*

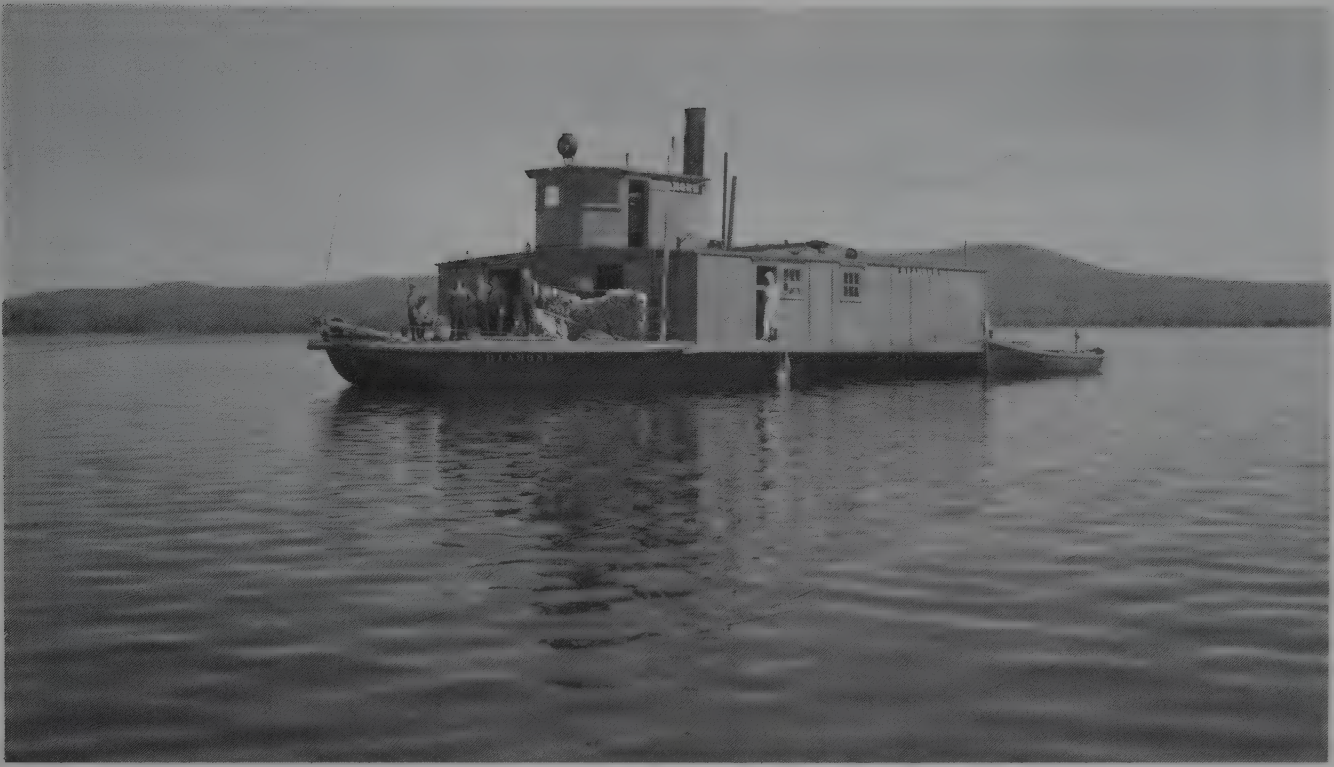


Figure 9. *(BM 679a) Brown Company lake steamer* Diamond *on Umbagog Lake in May 1938. This steam-powered vessel hauled the booms of pulp logs across the lake. Before the use of steam, the booms were moved across the lake by men turning capstans on anchored barges.*

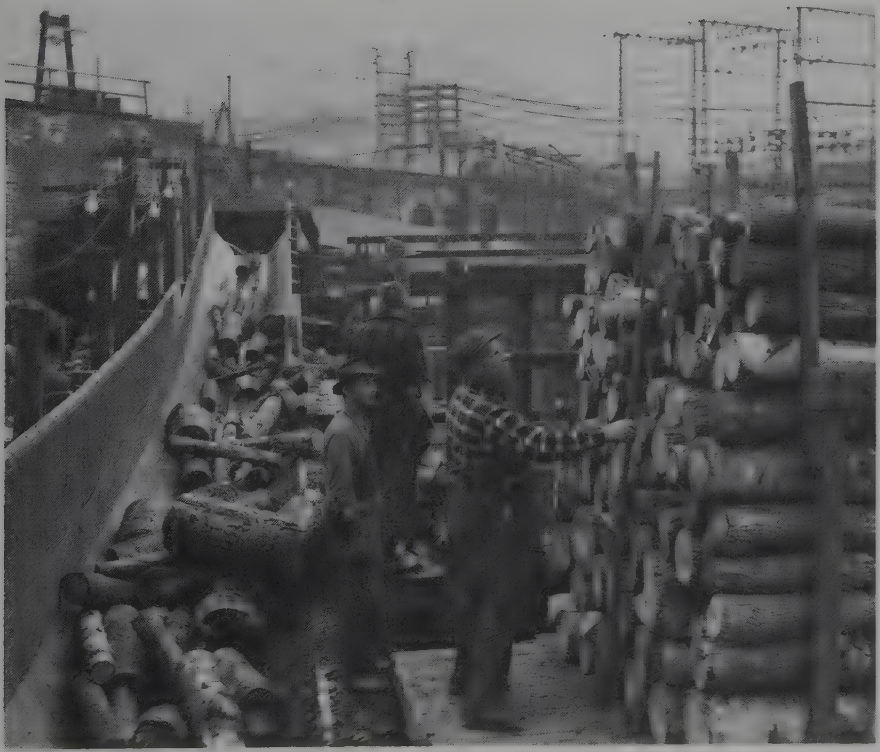


Figure 10. *(BM 1728a) Scaling (measuring the amount on the truck) a load of pulp on a truck prior to unloading at the Burgess pulp yard in Berlin. Wood was placed on conveyor behind the scaler (man holding the measuring rod in his right hand) for movement into the pulp yard. Photograph taken April 16, 1951.*

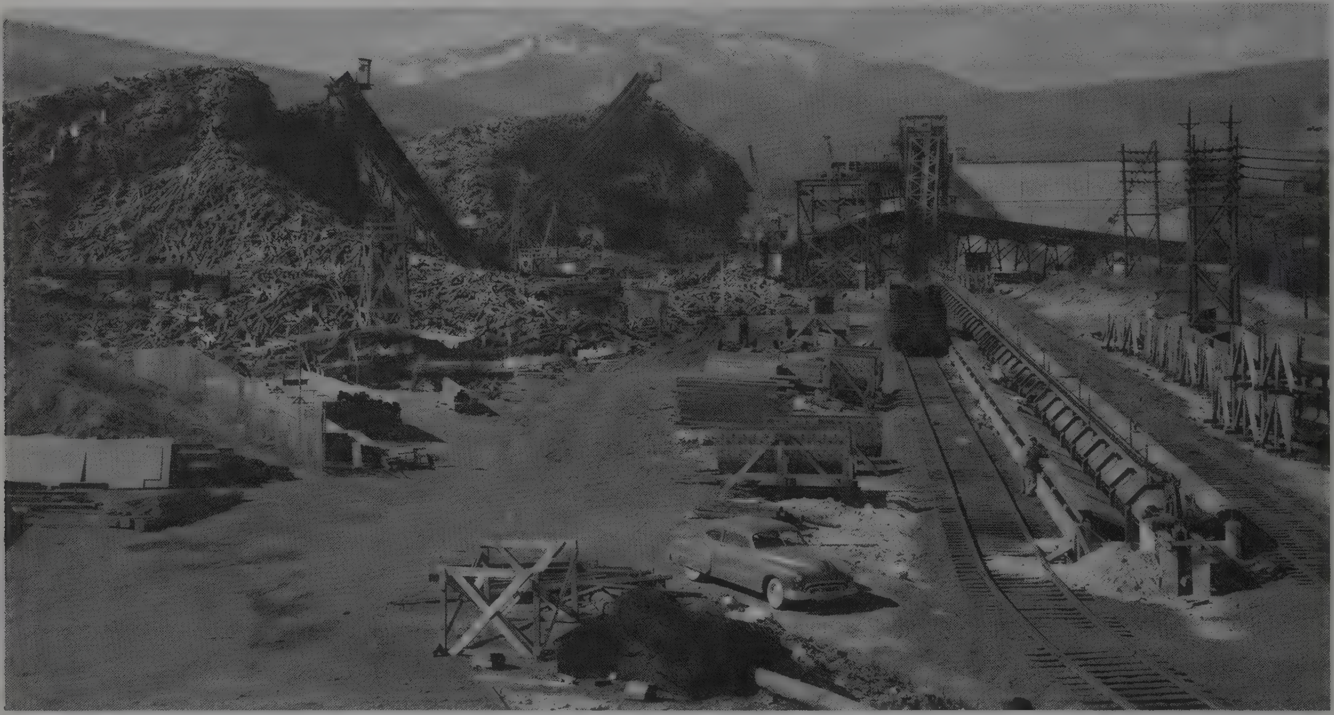


Figure 11. *(BM 1938) View of conveyor 1 and railroad unloading facility at the Burgess barker plant, April 1952. The size of the pulp piles indicates amount of wood the mills consumed. Railroad track with the gondola car on it is part of the Berlin Mills Railroad, which handled all of the internal switching of cars for the Brown Company mills. It connected with both the Boston & Maine Railroad and the Grand Trunk Railway. During the steam era it used small saddle tank engines. When it converted to diesels in the 1950s, the company purchased small industrial switchers. This view looking south also shows the snowcapped Presidential Range of the White Mountains.*

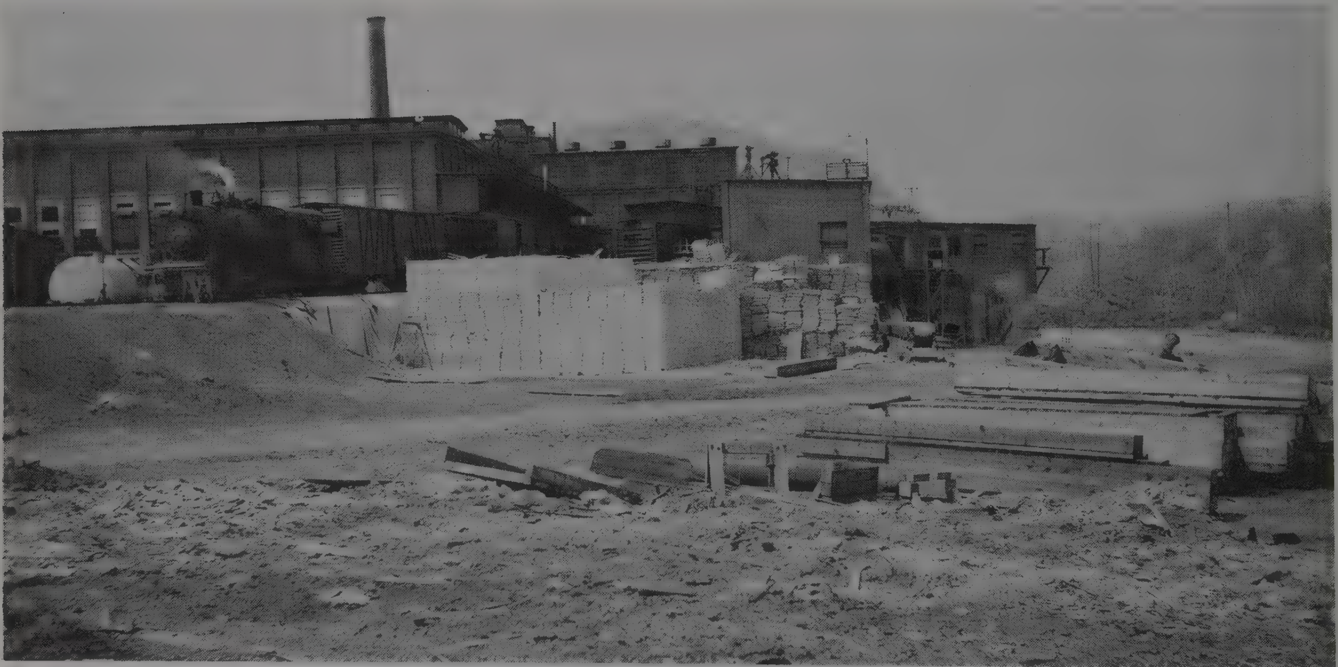


Figure 12. *(BM 932) Exterior of Cascade Mill in Gorham, N.H., May 1944. In the upper left of the picture is a Berlin Mills Railroad tank engine switching a load of boxcars for the mill.*

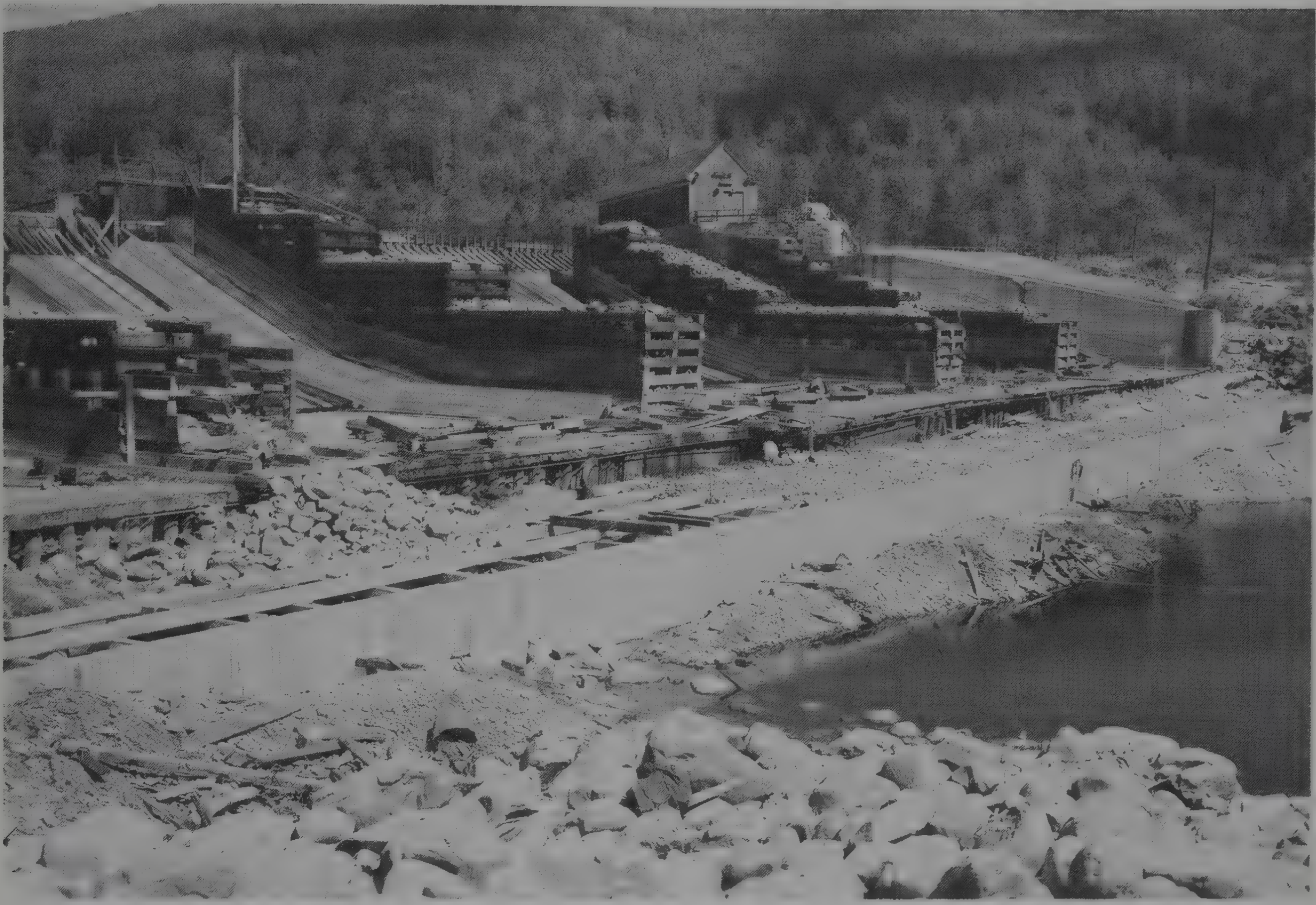


Figure 13. *(BM 779b) Brown Company owned several dams along the Androscoggin River. These were used for regulating water flow above the city of Berlin—especially during the driving season. Some dams, like this one in Gorham, the next town downriver from Berlin, generated electricity for use in the company mills. As the earlier views of the penstocks indicate, much of the power required by the company could be generated in its several hydroelectric plants. James River still generates a large percentage of the electric power needed to run the mills. This September 1941 view of the timber crib Gorham Dam shows it being repaired.*

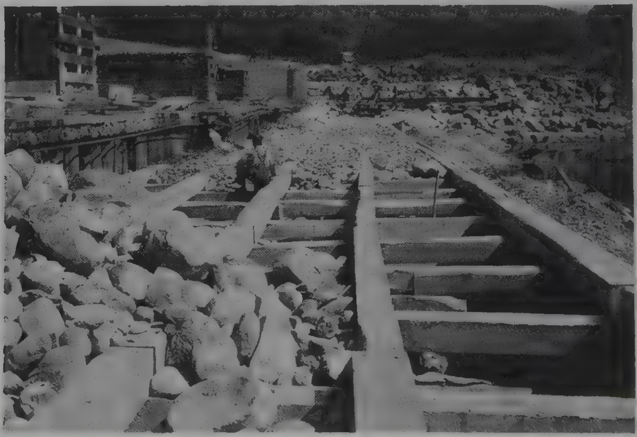


Figure 14. *(BM 779d) Detail of timber crib construction at Gorham Dam, September 1941.*

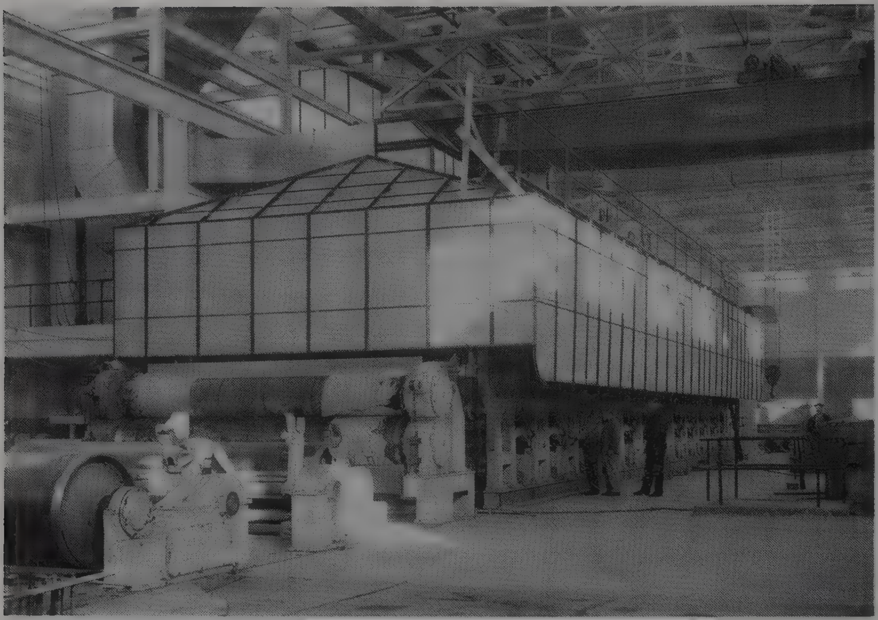


Figure 15. *(BM 1321a) New 196-inch paper towel machine installed in the Cascade Mill (Gorham, N.H.). Installation was completed in January 1948. Its size can be gauged by the three men next to the machine. For an indication of how paper machines had increased in size, compare this photograph with figure 2.*

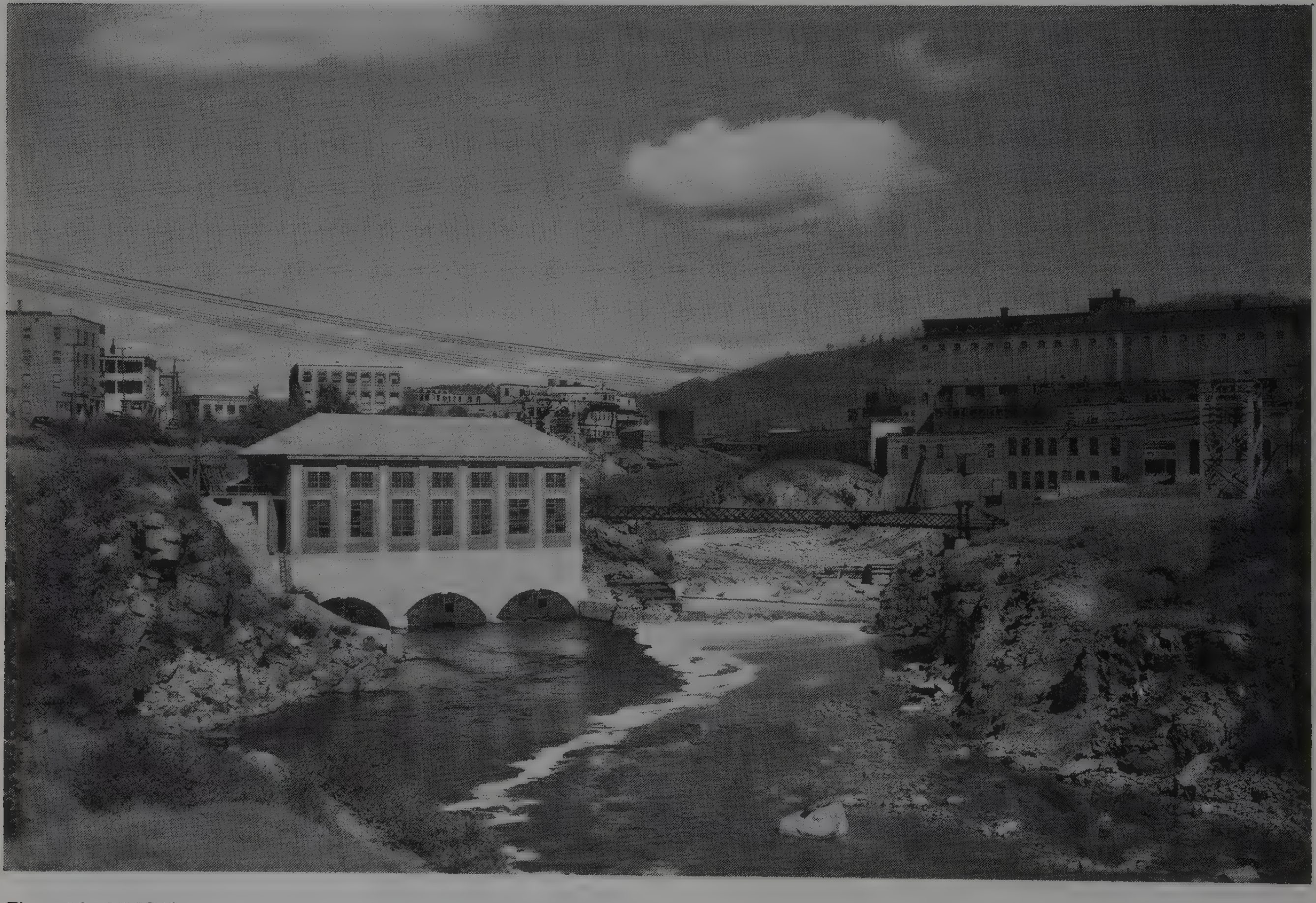


Figure 16. *(BM 776a) Brown Company powerhouse and mills in Berlin, August 1941. The drop in the Androscoggin River can be seen in the center of the picture. The main street of downtown Berlin is on the extreme upper left. Burgess Sulphite Mill (1892) is the large building at the upper right.*

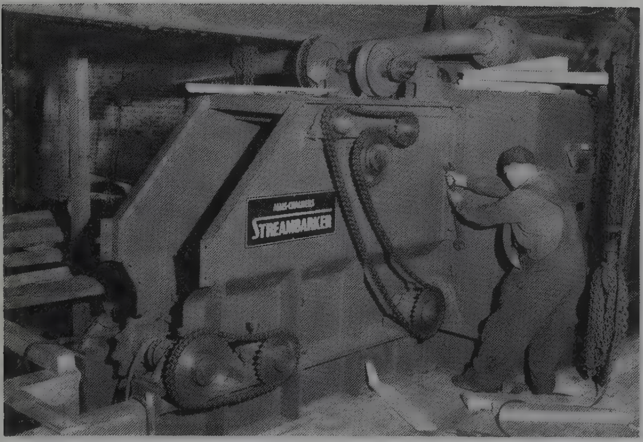


Figure 17. *(BM 947) Newly installed hydraulic barker in the Burgess Mill, June 1944. The position of the worker is reminiscent of a photo by Lewis Hine.*

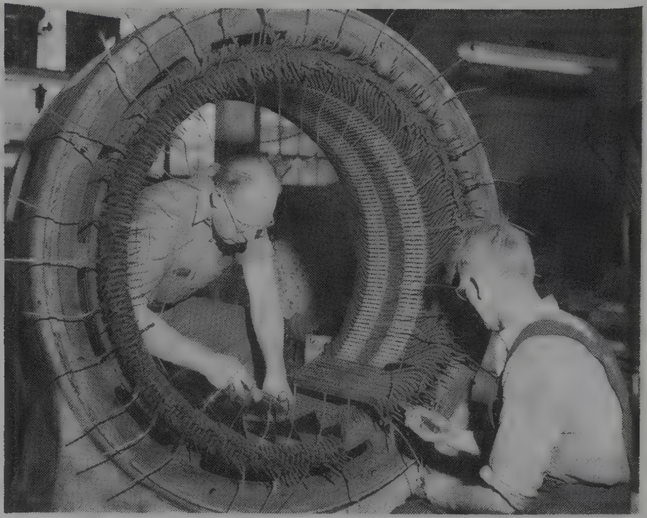


Figure 18. *(BM 1306f) Workmen in the electrical repair shop, December 1947. Many of these kinds of photographs appeared in* The Brown Bulletin *(the company employee publication) or were sent out with press releases for more general circulation.*

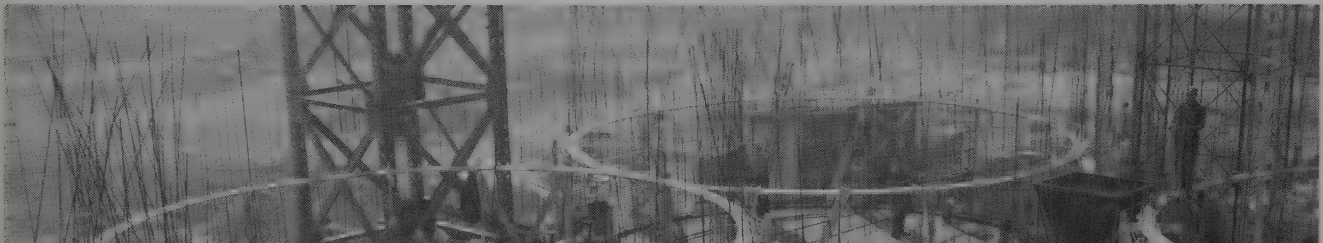


Figure 19. *(BM 1171a) Six kraft mill storage tanks under construction using what was called "sliding form-procedure of tank construction." Photograph taken October 10, 1946.*

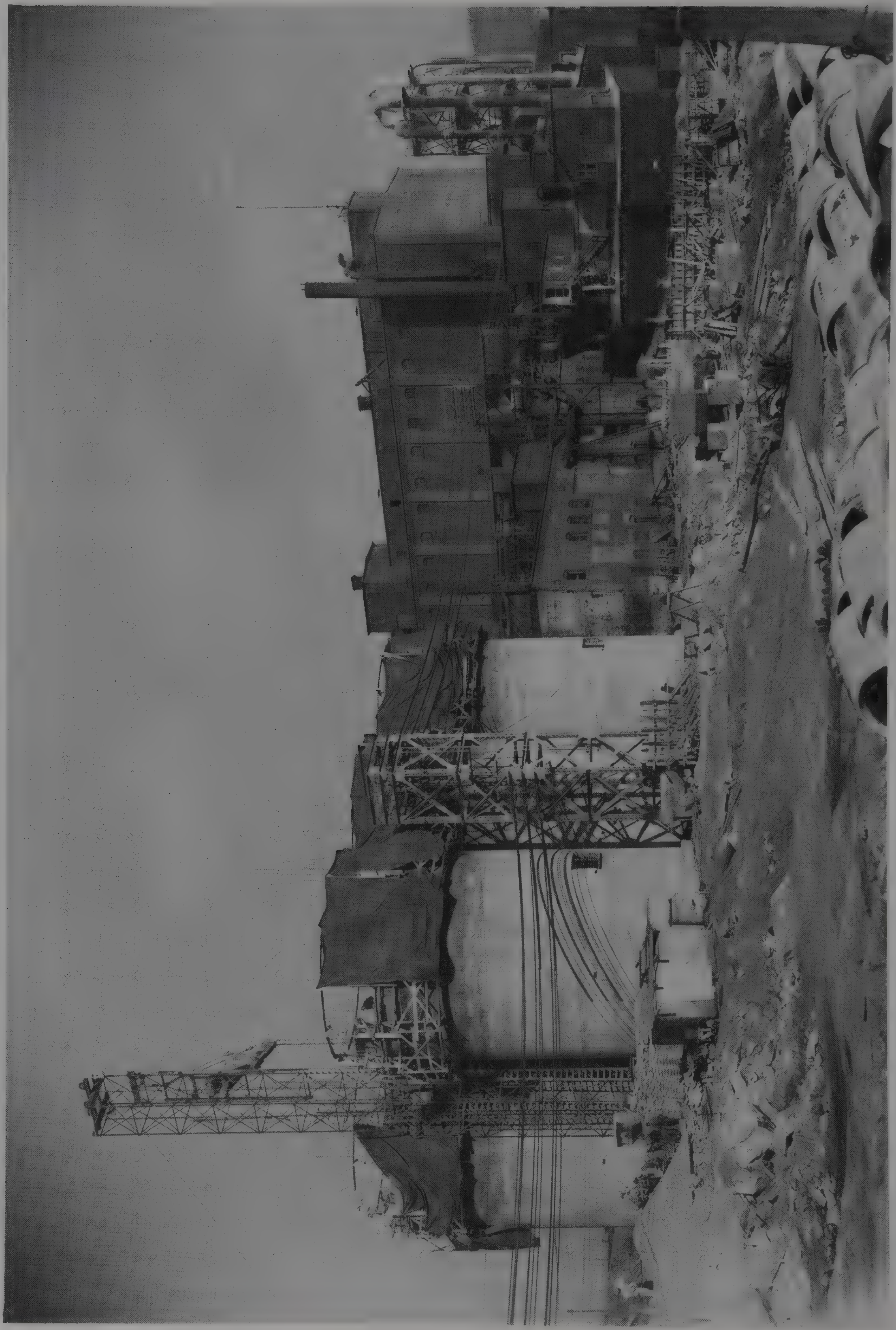


Figure 20. *(BM 1172b) View of kraft mill storage tanks under construction, the same shown in detail in figure 19. The concrete tanks are adjacent to the Burgess Mill. Photograph taken October 16, 1946.*

IA Reviews

200 Years of Soot and Sweat: The History and Archeology of Vermont's Iron, Charcoal, and Lime Industries. By Victor R. Rolando. Burlington: Vermont Archaeological Society, 1992. viii + 296 pp., illus., tables, glossary, bibl., index. Address inquiries to Mountain Publications, P.O. Box 1812, Manchester Center, Vt. 05255. $39.95 (cloth); $32.95 (paper)

Victor Rolando's *200 Years of Soot and Sweat* is a basic industrial archeological research volume that you will want on your bookshelf. Get one while they last. This is the first work attempting a statewide survey of several kinds of Vermont industrial archeological sites. It addresses all the sites employed by three types of industrial enterprises—ironworks, charcoal kilns, and lime kilns. In each case, a synthesis of the industry's history and evolving technology is given both for Vermont and to a lesser extent for North America. In each of the three processes, we receive a study of 200 years of industrial change as techniques evolved from folk to industrial technology. The survey portion of the work presents a synopsis of each site and a description of the aboveground remains that the author observed and studied during site visits. The locations are presented on maps and in 19 tables formulated by the author and organized by county. The entire work is profusely illustrated with historic drawings of sites and period photographs as well as historic product advertisements.

Surveys that cover all sites in a state are never as descriptive of any single site as a serious researcher might like, but they are very useful as an introduction and selective tool when assessing a site's potential to provide the answers to research questions. For instance, in my state, Boyer's *Early Forges and Furnaces of New Jersey* (University of Pennsylvania Press, 1931) is a book we use constantly as an initial research source. In comparison, Rolando's book is far more informative and complete and also covers charcoal kilns and lime kilns; it will become a basic research tool. For Vermonters, there is an additional benefit—a clearer picture of their cultural history. With this new knowledge, recognition, stabilization, interpretation, and historic preservation of the sites and their monuments should follow.

Any work of this size and complexity can be criticized. I am not satisfied with the accuracy of Rolando's evolution of American wrought-iron-making forges. My theories might be just as shaky, but I suspect much of the problem is that the questions we are asking cannot be definitively answered by the language used in the trade during the 18th and 19th centuries. The ubiquitous use of the word "forge" throughout our history presents just such a problem example. On page 93, figure 4-16, we learn that Jason Davenport, ironmaster of Wainwright Furnace at Middlebury Lower Falls, advertised in 1849 that his iron foundry and machine shop had "forge castings of all kinds on hand." So far, telling how these objects were made from this seemingly contradictory statement is beyond us. Davenport and his customers must have understood what was meant, but we can only guess. How will we ever settle these basic research problems? I suspect the answers may be found when we do in-depth research into the primary documentation and investigate the sites themselves. And we will use this book as one of our starting points.

My favorite parts of the iron section are the stories of the ironworkers: for example, the immigrant indentured servant boy who became a successful ironmaster after joining Vermont's Green Mountain Boys during the Revolutionary War and fighting in the successful capture of Fort Ticonderoga and the defeat of the Hessians in the Battle of Bennington; and the 15-year-old ironworks clerk who in 1816, "the year without a summer," drove the works' cattle to market in Montreal so that the remaining fodder could be used to sustain the merino sheep. What rich strands of American history these are.

The section on charcoal kilns presents much the same type of survey as in the iron portion. In this case, Vermont's kilns seem to be the most extensively employed in the country. As such we all have something special to learn from Rolando's syntheses, and Vermonters have an additional set of historic industrial monuments to consider. The last section, on lime kilns, has a very useful synthesis and its illustrated description of the evolution of a medieval craft into an industrial enterprise is as well presented as any I have read. Here perhaps is the most common furnace of our European culture and certainly one of the most common historic industrial monuments in our American landscape. For both charcoal kilns and lime kilns, I believe most industrial archeologists will be surprised at how undeveloped our knowledge of this rich historic context is.

The book ends with a very useful glossary, massive bibliography, and index that make using the work as a reference tool simple and accurate. However, I must note that the definition of a turbine as given in the glossary is inaccurate. Turbines are wheels that rotate by reaction to, rather than impulse from, the water under pressure that passes through them.

Edward S. Rutsch

Baltimore's Cast-Iron Buildings and Architectural Ironwork. Edited by James D. Dilts and Catharine F. Black. Centreville, Md.: Tidewater Publishers, 1991. xiv + 101 pp., illus., notes, bibl., index. $19.95 paper

Until displaced by structural wrought iron and steel, in many ways more versatile metals, cast iron was a much-used building material in the 19th century. It was cheap, lightweight, durable, fire-resistant, and quickly erected. Best of all, its ornamental possibilities were almost endless. The British first worked out the technology for producing structural cast iron in quantity at low cost. In the United States, New York architect-engineer James Bogardus helped win appreciation for iron architecture with his pamphlet *Cast Iron Buildings: Their Construction and Advantages*. In 1849 his iron-front Laing Stores in Manhattan caught the eye of Baltimore publisher Arunah S. Abell, who turned to Bogardus for the design of a state-of-the-art publishing center for his *Sun* newspaper. The five-story Sun Iron Building of 1851, a baroque assemblage with a complete iron frame and facade, was the first large commercial cast-iron building in America. It launched Bogardus's career and made cast iron acceptable in the building industry, at the same time giving Baltimore foundries an early and important exposure to what would emerge as a major industry.

Despite horrendous losses—a century ago, there were more than 100 iron-front buildings in Baltimore; today there are 10—the city still claims a notable share of the nation's cast-iron architecture. In *Baltimore's Cast-Iron Buildings and Architectural Ironwork,* editors James D. Dilts and Catharine F. Black celebrate that heritage with splendid photographs (most of them by Ron Haisfield) and a series of engaging essays. In "The Founder's Art," engineer and foundry manager J. Scott Howell explains the production and assembly of architectural castings and the restoration process. In separate essays, architect David G. Wright recounts the history of the Sun Iron Building (regrettably lost, along with more than 40 blocks of downtown Baltimore, in the great fire of 1904), while art historian Phoebe B. Stanton examines the Peabody Library of 1878. Lined inside with a magnificent six-story cast-iron front of neo-Grecian design, the Peabody Library continues to delight and inspire readers today.

Art historian Robert L. Alexander considers the city's decorative architectural ironwork, both cast and wrought. (Unlike brittle cast iron, a ferrous alloy high in carbon content, wrought iron contains almost no carbon and, because of its ductility, can be worked into a variety of shapes. Each piece is unique, even when a pattern is followed.) The book also reproduces two catalogs of the Hayward, Bartlett (later Bartlett, Robbins) foundry, Baltimore's premier architectural ironworks. Finally, a "Directory of Buildings" describes each of Baltimore's cast-iron survivors while offering up some wonderful nuggets, such as the fact that Baltimore claims to have produced the nation's first umbrella (1797); that native son H. L. Mencken's first sentient look at the world, described in *Happy Days,* was from the second-floor windows of his father's cigar factory, a cast-iron building on West Baltimore Street; and that window-shopping began with cast-iron architecture and the expansive storefronts it allowed. Amid such wealth, one is inclined to forgive a mangled reference to the *SIA Newsletter* (rendered here as *Journal for the Society of Industrial Archeology Newsletter*) and the repetition, in almost every essay, of the virtues of cast iron. Although the book might have been more tightly edited, it nonetheless is a worthwhile addition to the literature of architectural ironwork and a valuable starting point for the preservation of an ever-dwindling inventory of cast-iron buildings.

Carol Poh Miller

The Plum Beach Light: The Birth, Life, and Death of a Lighthouse. By Lawrence H. Bradner. Privately published, 1989. 196 pp., illus., appendixes, bibl.

Historians of lighthouse technology will welcome Lawrence Bradner's exhaustive account of Plum Beach Light, a landmark known to all who have crossed Narragansett Bay on their way to Newport, Rhode Island. Built 1896–1899, Plum Beach Light is a conical cast-iron tower resting on an iron caisson that descends more than 45 degrees into the sandy bed of the so-called West Passage; it is one of 11 United States lighthouses constructed by the pneumatic-caisson method.

Bradner's book is not intended as a scholarly contribution to the history of technology. Instead, it is a sort of documentary record of a labor of love, in which the author amassed every source of information on the lighthouse that he could find. In addition to local newspaper articles, interviews, diaries, and scrapbooks, Bradner made extensive use of widely dispersed Coast Guard archives and the papers of Rhode Island Senator Nelson W. Aldrich in the Library of Congress. A few sources commonly cited by lighthouse historians appear to have been overlooked: there are no references to coastal-pilot handbooks, nor any citations of contemporary engineering journals. The author has synthesized all of his information into well-organized chapters covering the need for the lighthouse, its construction, and its four decades of service.

Footnotes are commonly perceived as an impediment in popular history, but this book suggests that they have a place in such works. Bradner is scrupulous in recognizing his sources of information and interpretation, and while his attitude is applaudable, the text constantly gets bogged down in acknowledgments. Bradner also seems to have a need to tell us not only what he has discovered, but how he came to his conclusions. Although many of the key documents are included in appendixes, others are quoted at length in the text, with too much exegesis and weighing of evidence. Bradner should have more confidence in himself as a researcher and historian. With footnotes for those who wish to judge his evidence, he could have stated his conclusions more directly and thereby improved his text.

Such quibbles aside, readers will discover many useful and thought-provoking items. One of the best sections recounts in detail how steamship interests and city-booster types in Providence carried the burden of lobbying for the lighthouse. Bradner also presents extensive statistics showing how the number and size of vessels increased in the late 19th century, requiring better aids to navigation to avoid such disasters as the wreck of the passenger steamer *Rhode Island* in 1880. In addition to passenger travel, Rhode Island's highly developed industrial sector generated a substantial demand for coal, which made up the bulk of the ever-increasing schooner and barge traffic.

Bradner does a fine job explaining the technology of the lighthouse's construction in terms understandable to the general reader. Engineering for deep foundations was subject to great uncertainties at the time, as Plum Beach Light made painfully clear. Despite extensive borings, the caisson was found to be perched over a layer of quicksand when it had been sunk to the depth called for in the contract, a circumstance that delayed the light's completion for several seasons.

Plum Beach Light also offers a wealth of local lore regarding the light, its keepers, and its role in the life of neighboring communities. The account of the Great Hurricane of September 1938 is especially full and successful in conjuring up a world before weather satellites. Ironically, it was not the hurricane but another work of engineering that brought an end to the lighthouse; the channel lights of the Jamestown Bridge, completed in 1940, made the lighthouse redundant, and it was discontinued soon thereafter. With Plum Beach Light's future uncertain, Lawrence Bradner's book makes a real contribution by delineating the lighthouse's significance in technological and maritime history.

Bruce Clouette

The Men and the Mills: A History of the Southern Textile Industry. By Mildred Gwin Andrews. Macon, Ga.: Mercer University Press, 1987. xvi + 367 pp., illus., glossary, bibl., index. $35.00

This is a collective corporate-level history of the executives and entrepreneurs who established and developed the South's textile industry. As stated in the epilogue, "the author's primary asset was her personal experience in working with many of the men who shaped the industry." Mildred Andrews served for many years as executive secretary of the American Textile Machinery Association, and this key position provided her an insider's view of the industry as a whole. She has taken full advantage of this in presenting a detailed picture of an important industry, especially its intimate association with the Southern Railway. There are photographs and drawings for the entire time period covered (1880 to 1987), showing mills, machines, and portraits of some of the individuals concerned.

The treatment is primarily chronological, presented in 14 chapters. The railroads are mentioned throughout the narrative, showing the important place they held in the lives of these men. The trains often served as a business-office-on-wheels as the executives shuttled between mills; the format of the last chapter is a ride on the *Crescent,* with a description of the mills it serves. This condensed quotation is representative of the gems scattered through the narrative: "Speeding south, one can see historic King's Mountain from the windows of the Crescent. A good-sized textile company there, the Neisler Mills, owed its beginning to the Southern's luxury dining cars. [Neisler] . . . had secured a fine lifetime contract from the Southern Railway to provide tablecloths and napkins for its luxurious dining cars. Neisler intended to build a cotton weaving mill with Compton & Knowles Jacquard looms . . . and make the finest cotton damask for napery. . . . [Neisler] supplied the Southern Railway with napery until Amtrak switched to paper napkins."

The Men and the Mills includes discussions of labor relations, the Depression, and disposal of mill village real estate, all considered from the corporate perspective. This is a useful complement to the social history of the workers as presented in such recent works as *Mill Family, Like a Family, Habits of Industry,* and *Hard Times Cotton Mill Girls.* It fills in the technical details and entrepreneurial development that support the theme developed in *Independence and Empire,* the title of which suggests the two philosophical reasons for the beginnings of the southern textile industry.

Andrews's experience is put to especially good use in the discussions of trade associations, textile machinery manufacturers, and mill engineers. Two extensive chapters are devoted entirely to the development of textile machinery in the 19th and 20th centuries. The entire process is presented, from outside the mills (harvesting and ginning), through the complete manufacturing procedure (opening the bales, carding, roving, spinning, weaving, and other intermediate processes). These chapters are generously illustrated with a series of prints from the mid-19th century (from the Yale University Library), and a series of cuts from Frank Leslie's *Illustrated Newspaper* of April 16, 1881. The prints are reproduced in black and white, a half-page each. Clarity is adequate to accompany the text, but they would have been much more impressive as full-page full-color plates. There are also photos and drawings of a few patent models. These chapters do a good job of showing the synergism of the development process when entrepreneurs are in a position to take advantage of the cross-pollination of ideas from talented engineers like Moody, Northrup, and Draper.

The epilogue briefly chronicles the reshaping of the textile industry through the mergers and acquisitions of the mid-1980s. The end of the narrative is marked by a report of the International Textile Machinery Exhibition in 1987. By then, for the first time, imports captured over half of the U.S. domestic market for textile machinery; in 1960 American manufacturers supplied 93 percent of the domestic market.

The Men and the Mills provides cogent insight into the symbiotic relationship between railroads and the premier industry of the southern piedmont, as well as a useful review of the technical development of that industry.

John Austen

Weaving a Common Thread: A History of the Woolen Industry in the Top of the Shenandoah Valley. By Wilbur S. Johnston. Winchester, Va.: Winchester-Frederick County Historical Society (1340 South Pleasant Valley Road 22601), 1990. xii + 239 pp., illus., appendixes, bibl., index. $28.00

As this book's subtitle indicates, the work is primarily a business history of Virginia Woolen, ultimately the dominant firm in the region, with enough background to establish a historical context. Virginia Woolen, in business from 1900 to 1955, shared in the growth and decline of the textile industry in the United States and is representative in many ways; however, Wilbur Johnston contrasts the corporate form of ownership (as practiced by Virginia Woolen) with sole proprietorship as practiced by some of Virginia Woolen's predecessors and competitors.

The book begins with a general history of the region and of the processing of wool. Special attention is devoted to the area's rural woolen mills from the 18th through the mid-19th centuries and to other urban woolen factories in the region, most of which were involved with Virginia Woolen in one way or another (e.g., through interlocking directorships). This is followed by a history of Virginia Woolen in Winchester, including development of the plant (construction dates and details) and the entrepreneurial history of the corporation. A concluding section offers biographical sketches of 39 of the leading men in the industry, mostly directors or officers of various companies who were involved directly with Virginia Woolen.

The 10-page bibliography shows extensive research in primary sources (letters, company documents, court records, etc.) as well as newspapers and a few secondary sources, many not generally available. The maps (over two dozen) are especially well done. Each factory or site is located on a detailed (but uncluttered) road map, should you wish to visit it. But the most interesting "maps" are in fact plans of several of the factories at various stages of their development. Most of these also include a schematic elevation showing the use of each floor in the building (carding, spinning, weaving, etc.).

Weaving a Common Thread is illustrated with about 100 photographs. There are photos of most individuals covered by a biography, as well as groups of other workers. A carefully chosen series shows the buildings as they existed at diffferent stages of development. A few interior shots are also included. The photos accompany the text to which they pertain, and the reproduction quality is good. This well-written book will appeal to many members of the SIA. It is a fine example of local history, and as such is worthy of emulation.

John Austen

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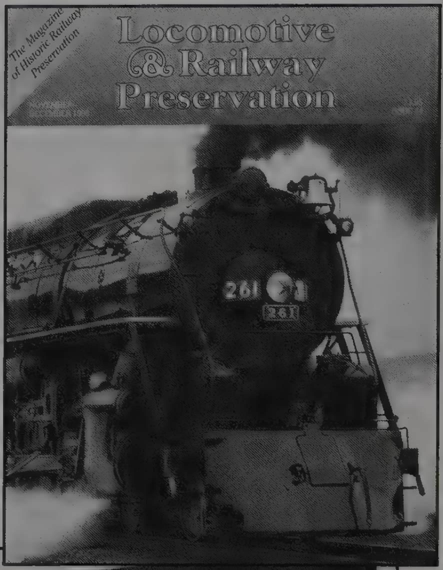

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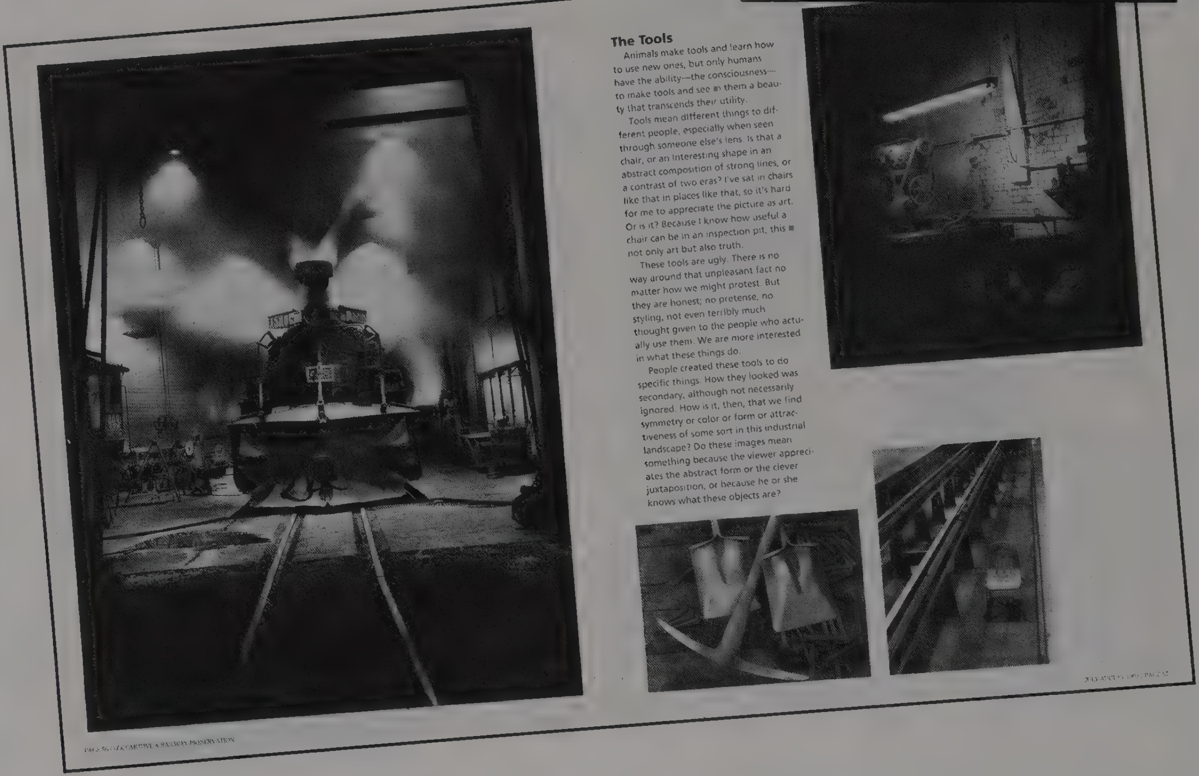

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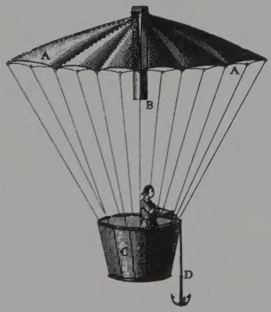

CATALOGUES SENT UPON REQUEST

IA Contributors to This Issue

John Austen is an IA researcher who lives in Virginia and is interested in the history of textiles and railroads.

Bruce Clouette is Senior Historian with Historic Resource Consultants, Inc., a research firm in Hartford, Connecticut. With Matthew Roth, he is the author of *Connecticut's Historic Highway Bridges*. In 1983, Clouette and Roth photographed, researched, and wrote a preservation plan for 33 historic Coast Guard-owned lighthouses.

Dennis E. Howe is self-employed and holds electrical engineering degrees from Lowell Technological Institute (now the University of Massachusetts, Lowell). He has been active in archeological research and writing for many years.

Emory L. Kemp is Professor of Engineering and Director of the Institute for the History of Technology and Industrial Archaeology at West Virginia University. He is the first recipient of the Society for Industrial Archeology General Tools Award for Distinguished Service to Industrial Archeology.

Carol Poh Miller is a historical consultant in Cleveland, Ohio.

Edward S. Rutsch is a principal member of Historic Conservation and Interpretation, Inc. He is a founder and longtime member of the Roebling Chapter of the SIA.

David H. Shayt cares for handcrafted collections and their tools at the Smithsonian Institution's National Museum of American History. His research and collecting interests in materials processing include leather glove-making, diamond-cleaving, and pearl button manufacture.

William L. Taylor is Professor of History and Director of the Institute for New Hampshire Studies at Plymouth State College which is the repository of the Brown Company Photograph Collection.

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Abstracts of about 50–100 words are required to introduce each article or research note.

Footnotes and captions are typed in the same manner as the text, on sheets following it. In general, the University of Chicago *Manual of Style* is the guide.

Examples

1. Abbott Payson Usher, *A History of Mechanical Inventions,* 2d ed. (Cambridge, Mass.: Harvard University Press, 1954), pp. 433-443.
2. Jack S. Blocker, Jr., "Anthony F. C. Wallace's *Rockdale,*" *IA* 6, 1 (1980):63-65.
3. Usher (n. 1 above), p. 15.
4. John J. Greenough to Jonathan Lane, January 4, 1869, Lane Papers, Records of the National Bureau of Standards, Record Group 167, National Archives, Washington, D.C.

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Spelling and usage follows *Webster's New Collegiate Dictionary.* Neologisms should be avoided. Note the spelling of "archeology," "workplace," "work force," "waterpower," "waterwheel," "ironmaking," "ironworker," and "ironworks." Personal pronouns are to be avoided in all but review articles, and gender-specific pronouns used only if the reference is to a specific person. Dates are written as follows: 19th century, 1970s, June 7, 1944, June 7, or June 1944. States and provinces are abbreviated in the traditional way (Cal., Mass., Mich., Ont.). Numbers one through nine are spelled out; others are not, except when they begin a sentence. Circa is noted as follows: c1890. Punctuation usually falls within closing quotes. In a series consisting of three or more elements, the elements are separated by commas. For general rules regarding capitalization, abbreviation, italics, brackets, and ellipsis marks consult this issue of the journal or the University of Chicago *Manual of Style*.

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